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J. S. FOOTE, M.D.

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A CONSTRUCTIVE METHOD IN HISTOLOGY

BASED UPON THE TUBE PLAN OF STRUCTURE OF THE ANIMAL BODY WITH CASE OF MODELS FOR DEMONSTRATION

BY

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PUBLISHED BY
F. L. BRADBURY
NAUGATUCK, CONN.
1907

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PREFACE.

In presenting a Constructive Method in Histology the writer is conscious of a somewhat radical departure from the usual plan followed by books upon the subject. It seems, therefore, desirable to explain in some detail the principal reasons for diverging from the methods ordinarily adopted by most authors. Experience in teaching leads one to the conviction that those beginning the study of histology find more or less difficulty in forming a clear conception of the subject and are quite likely to fall into the habit of committing to memory descriptions of structures which they either have not seen or can not see without some experience in gross anatomy and in the use of the microscope.

In some cases they have no knowledge which enables them to assimilate the new and complex ideas to which they are abruptly introduced. Under these circumstances, to present a series of isolated facts which have little or no apparent connection with the facts of allied subjects, is to violate a fundamental principle of the mind's development. It has long been recognized by educators that such facts are mere symbols possessing no impulsive power, and hence producing no lasting results. The mind finds satisfaction in the organization of its ideas. There is a certain intellectual pleasure and profit in following the orderly and progressive development of a subject which takes as its point of departure some fact or group of facts which fall within the experience of all.

Histology is one of the fundamental branches of medicine and is useless to the majority of medical students unless it has some definite bearing upon medicine. As a rule, it is not easily committed to memory because its facts are not easily understood. In those cases which are successful on account of persistent application, the knowledge acquired exhibits a vague and devitalizing character which confuses the student and leads him into error or indifference. The subject is usually taught during the freshman year at a time when the anatomist is teaching osteology and myology: consequently, when the histologist takes up the tissues and refers to their part in the construction of the various viscera, the student may not even know what or where those viscera are and receives no direct information from his anatomical course. It is almost useless, for example, for a teacher to describe transitional epithelium as it occurs in the pelvis of the kidney, ureters and bladder if the student does not know the locations or purposes of these organs. He may take the trouble to enlighten himself on this point, or may, instead, commit facts to memory only to forget them more easily than he committed them. It can not be expected that he knows really anything about the viscera if he has never seen them or heard them described. On account of this fact, a few plates of gross anatomy are introduced to enable the student to form some conception of the locations and relative positions of the more important viscera, the structures of which he is expected to know, perhaps, before dissection or even simple observation affords him that information. The most important reason, therefore, for this departure from the customary course in histology, is to employ the constructive faculties of the mind as they are based upon observation instead of its purely memorizing capacities. If we believe that the mind is fundamentally an activity rather than an organ for receiving and recording impressions, we shall readily agree that its constructive powers are of primary importance where a mechanism is concerned. It is only when the mind is employing its native capabilities in the solution of problems which it has formulated for itself, and in the elaboration of which all its energies are voluntarily enlisted, that knowledge of permanent value can be attained. Such intellectual labor is far removed from that of merely receptive or memorizing processes, and experience shows that knowledge thus acquired becomes an integral part of the mind's capital. This work is intended to provide, in concrete form, for the constructive activity of the normal mind. It consists of two parts, viz: a descriptive text setting forth the constructive method based upon tube formations, and a case containing building models and the outlines according to which the organs are constructed. The tube is taken as a fundamental, structural and functional unit of visceral formation. It has motor and non-motor characteristics which are believed to be extremely important as guides in the formative plan of visceral structures. The value of some sort of manual work in connection with mental activity is conceded by most educators. By means of the accompanying models students may learn to construct any tube of the animal body and thus may find, not only a medium for motor expressions, but also a method of clarifying and classifying facts already partially grasped. Moreover the constructive process tends to produce concrete results which are capable of practical application. The problem of what to learn and what not to learn confronts the student in every branch of study. Not possessing a judgment trained in the distinction of values, he must select from all available sources what his previous experience leads him to believe is important and omit the remainder. Errors in judgment are frequently made and to this source may be traced much of that vague knowledge which is devoid of all dynamic power. In the construction of any complex mechanism the builder usually follows some design more or less completely developed and the finished structure is a visible interpretation of that design. As a result the builder is not burdened with materials which he does not use and the structure is not rendered worthless by reason of the extraneous matter which has been added to it without reference to a rational design. The constructive method is believed, therefore, to be the most satisfactory method of approaching the subject of histology. The animal body is a mechanism and most of the organs of this mechanism are tubes which are composed of various tissues. These tissues are arranged according to a particular design which best serves the requirements of the tube. If we have the tissues and know the design we can construct any organ of the body. This is the object of the accompanying models. They all have the same curve and are intended to represent cross-sections of tubular structures. The circles employed in their formation have the same diameters. The same curve is employed for both the large and small tubes in order that the number of models may not be in excess of convenience as building materials. Upon them are printed, somewhat diagrammatically, the different tissues and their varieties—epithelial structures in pink, muscular in red and connective tissues in white. The nuclei in all cases are blue. These colors are intended to represent the hæmatoxylin and eosin stains. The word outlines which are printed upon the inside leaves of the case form the design or plan according to which the organs are built. The numbers at the left of the models are for the convenience of the beginner. They may be disregarded as soon as the tissues are familiar. The numbers beneath and at the right of the word outlines are model numbers which may also be disregarded as soon as the tissues are known. The details should be worked out in the laboratory under the direction of the teacher. It is essential that students have a knowledge of tissues and cells before the constructive process begins. This method then, departs from the customary at that part of the histological course, which is concerned with the study of organs or viscera. This work is not intended as a complete text-book of histology for there are many very excellent books already. It is designed as a teaching method based upon simple observation and a teacher's experience; and by its use both teacher and student may be more closely brought together, being engaged in the actual construction of something of common interest. If teacher and student can actually build a mechanism by means of materials which are in their possession, the completed structure really means much more than a simple mental act could possibly accomplish. Furthermore, the simple act of construction develops the physiological reasons for histological structures and thus correlates the whole. The plates used have been taken from well known text-book sources, re-drawn, and adapted to tube structures. This method, employed as a means to an end, is thought to constitute a useful scheme for the acquisition of a knowledge of a subject somewhat difficult in character. It is not supposed that the book, outlines and models are free from errors. On the contrary the nature of the subject is such that errors are almost inevitable. However a new method of teaching and of learning histology is presented, the application of which will determine its value.

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Creighton Medical College,
Omaha, Nebraska, 1906.

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PART I

SECTION I

CELLS AND TISSUES AS BUILDING MATERIALS

GENERAL OUTLINE.

Observation with the naked eye shows one that a living animal eats, breathes, moves, expels waste matters, reproduces its kind, bleeds when cut, smells, tastes, feels, hears and sees. From this observation it is evident that it must have certain definite parts which are set aside for these purposes. These parts, called systems, are the general divisions of the body. They are named according to the various functions which they perform, as—digestive, respiratory, muscular, urinary, genital, circulatory, sensory, etc. Observation by dissection shows that all of these systems are composed of smaller parts. These are called organs. They have received their names from anatomical and physiological observers of remote dates and do not appear to present any family relationship. Naked eye observation terminates here. Investigation, which is then possible by means of the microscope, shows that the organs are composed of smaller parts. These are called tissues—four in number. Further investigation shows that the tissues are composed of smaller parts called cells, and intercellular substances. The cells are found to be composed of still smaller parts which, at the present time, remain as the ultimate structures of the animal body. This method of analysis affords us a general view of the constituent parts of the body and also of the body as a whole and is presented in the outline which follows. The historical and histological structures of the cell are indicated in plate I. which follows the outline.

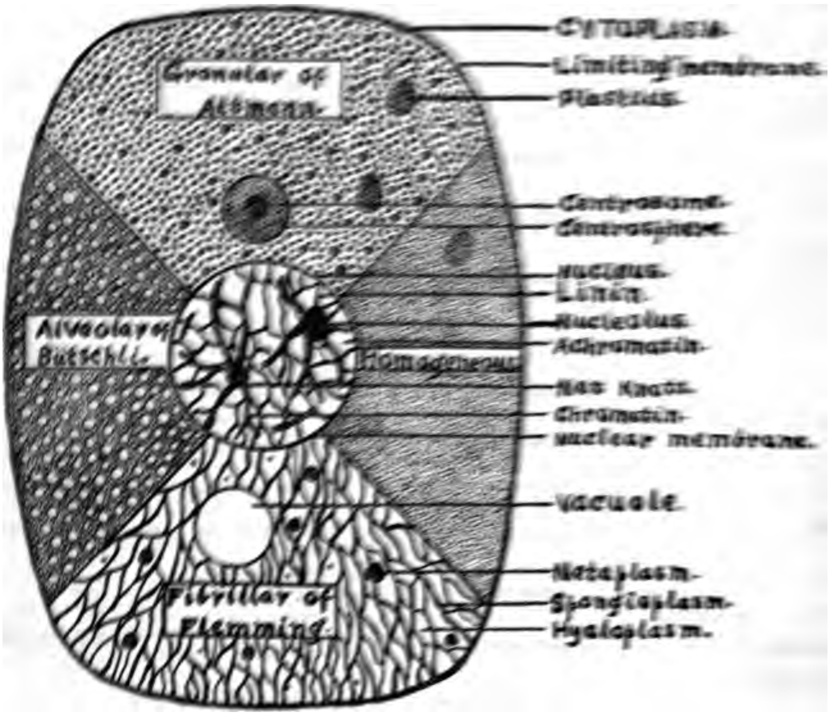
OUTLINE OF THE GENERAL STRUCTURES OF THE ANIMAL BODY.

	Systems.	Organs.	No. of Tissues.	Tissues.	Varieties of Tissues.	
Animal.	1. *Circulatory.**	1. *Heart.** 2. *Blood vessels.* 3. *Capillaries.* 4. *Lymphatics.*	Four.	1. Epithelium.	1. Simple.	Pavement, Squamous, Tessellated, Scaly or endothelium.
	2. *Digestive.*	1. *Mouth.* 2. *Salivary glands.* 3. Tongue. 4. *Œsophagus.* 5. *Stomach.* 6. *Intestines.* 7. *Liver.* 8. *Pancreas.*				Glandular, Polygonal, Polyhedral. Columnar, Cylindrical, Cubical, Ciliated.
	3. *Respiratory.*	1. *Larynx.* 2. *Trachea.* 3. *Bronchi.* 4. *Lungs.*			2. Stratified.	Pavement, Squamous, Tessellated, Scaly.
	4. Nervous.	1. Brain. 2. Spinal cord. 3. Ganglia. 4. Sympathetic, Centro-spinal Nerves.			3. Transitional.	Stratified.
	5. Muscular.	1. Skeletal. 2. Visceral. 3. Heart.				
	6. Osseous.	1. Long bones. 2. Flat bones. 3. Irregular bones.				
	7. *Genital.*	1. *Uterus.* 2. *Fallopian tubes.* 3. *Ovaries.* 4. Labia majora. 5. Labia minora. 6. Clitoris. 7. *Penis.* 8. *Testicle.* 9. *Vasa efferentia.* 10. *Epididymis.* 11. *Vas deferens.* 12. *Vesiculae semin.* 13. *Prostate gland.* 14. *Cowper's gland.* 15. *Littré's glands.*		2. Connective	1. Blood. 2. White fibrous. 3. Yellow elastic. 4. Areolar. 5. Mucous or embryonic. 6. Adipose. 7. Lymphoid, adenoid, retiform, reticular 8. Cartilage. 9. Bone. 10. Neuroglia.	
	8. *Urinary.*	1. *Kidneys.* 2. *Ureters.* 3. *Bladder.*				
	9. Sensory.	Eye, ear, nose and appendages.		3. Muscular.	Striped voluntary, Striped involuntary, Unstriped involuntary.	
	10. Not Classified.	1. Lymph node. 2. Thymus, thyroid. 3. Adrenals. 4. Spleen. 5. Pineal gland. 6. Pituitary body. 7. Coccygeal gland.		4. Nervous.	Neuron. Nerve cells, fibres. Neuroglia.	

* Words in italics indicate tube systems and organs.

OUTLINE OF THE GENERAL STRUCTURES OF THE ANIMAL BODY.

STRUCTURE OF A TISSUE.	STRUCTURE OF A CELL.		DESCRIPTION OF MINUTE STRUCTURES.
	GENERAL.	MINUTE.	
1. Cells.	1. Cytoplasm.	1. Cell membrane.	Product of cell cytoplasm surrounding the cell. Living or lifeless.
		2. Spongioplasm.	Fibrillar, alveolar, or granular meshwork—active or passive.
		3. Hyaloplasm.	Structureless, labile, ground substance in the meshes—seat of metaplasmic deposits.
		4. Attraction sphere.	Radiating, astral, protoplasmic substance active in cell division.
		5. Centrosome.	Single or multiple granules within the attraction sphere. Dynamic center of a cell.
		6. Plastids.	Substances which by growth and division become starch, chlorophyll or pigment.
		7. Vacuoles.	Spaces occupied by a liquid.
		8. Metaplasm.	Passive granules, either foods or waste products of cells.
	2. Nucleus.	1. Nuclear membrane.	Extended chromatin layer surrounding the nucleus.
		2. Chromatin.	Vital, staining substance, causing cell division and cell phenomena.
		3. Achromatin.	Colorless liquid occupying nuclear network.
		4. Nucleolus.	Small bodies which stain like cytoplasm, the function of which is not understood.
		5. Chromatin knots.	Small aggregations of chromatin.
		6. Linin.	Reticular base which stains like cytoplasm, supporting nuclear structures.
	STRUCTURE OF BASE OR INTERCELLULAR SUBSTANCE.		
2. Base.	It occurs between cells as a base and may be either cement, fibres or both. There are reasons for supposing that between all cells adjacent to each other there is an organic continuity in the form of intercellular bridges.		



THE CELL.

PLATE I.

HISTORICAL AND STRUCTURAL DIAGRAM.
The four theories of cytoplasmic structure and the various parts of which the cell is composed.

THE CELL.

The cell is a chemical and mechanical unit of structure, the phenomena of which depend upon the peculiar manner in which the terminal is constructed. It is composed of the chemical elements, C, H, O, N, S, P, Na, K, Ca, Mg, and Fe, arranged in some definite form, which is known as protoplasm. Within protoplasm certain chemical changes are constantly in progress with the liberation of energy—the direction of the energy depending upon the cell mechanism. As the blood, the common source of chemical supply, is always constant in its chemical constituents and always contains all the elements of protoplasm, certain variations in mechanism must occur in different cells in order to account for the differences in cell products and activities. Thus cells may secrete milk, bile, ptyalin or mucus, may excrete urea or water, may shorten and lengthen—causing motion, may divide and construct new tissue, or may liberate accumulated energy at the moment of irritation. They are not homogeneous in structure; but are composed of many parts—the functions of these parts added together forming the function of the cell. The cell is a complex structure. It always has two parts—cytoplasm and nucleus. The cytoplasm may comprise a limiting or cell membrane, spongioplasm, hyaloplasm, plastids, vacuoles, and metaplasm. The nucleus may contain a nuclear membrane, chromatin, achromatin, nucleolus, chromatin knots and linin. This makes a heterogeneous structure exceedingly intricate in character. All of the parts above mentioned are not found in every cell; but every cell contains many of them. No two of them are precisely alike and hence do not have exactly the same office: so that if a variation in the possession of the parts is possible, a variety of functions must be allowed. A brief consideration of these various structures is necessary.

Cell Membrane.—Cytoplasm is almost midway between a liquid and a solid, perhaps it is just within the limits of a solid. The outer limiting membrane is the analogue of the slightly condensed ectosarc of the one celled animals. An enclosing membrane of varying density would be advantageous to the semi-solid protoplasm or cytoplasm as it is well adapted to the purposes of protection, osmosis and retention of the labile parts within. It would vary in density according to the movable or fixed character of the cell; so that in a wandering cell the least degree of density would be essential while in a fixed or vegetable cell the highest degree would be required and between these extremes all degrees would be found according to the nature of the cell.

Spongioplasm and Hyaloplasm.—The division of cytoplasm into two parts is the outcome of many observations made upon many cells. During the early period of microscopical experience cytoplasm was generally considered as a homogeneous structure and within it was located the nucleus. Improved microscopes and technique however enabled different observers to distinguish two parts which have received many names --among them spongioplasm and hyaloplasm. By spongioplasm, is understood a reticular structure which stains with some aniline dyes and by hyaloplasm the labile, unstainable contents of the meshes of the spongioplasm. The structure of cytoplasm has been subject to several modifications according to different observers and to the character of the cell examined. Flemming described it as composed of a delicate network of fibrils enclosing the structureless hyaloplasm. The net-work was the spongioplasm. Altmann described it as made up of small granules capable of nutrition, growth and division. This theory made cytoplasm a coöperative community of individual parts, the combined functions of which established the function of the cell. Bütschli described it as alveolar in character, which condition was due to the presence of minute globules. He made emulsions of olive oil and found that the structure and appearance of the emulsion resembled the structure and appearance of cytoplasm so closely that in most instances it was difficult to distinguish between them. Later observation has resulted in the conclusion that cytoplasm may be homogeneous, granular, fibrillar or alveolar according to the age of the cell and these different structures may be associated with graded processes of cell activity. Within the cytoplasm are found other bodies which are sufficiently permanent to be regarded as essential to the cell. Something of the importance of these bodies may be understood from the following descriptions of them.

Attraction Sphere and Centrosome.—The attraction sphere is a spherical body usually situated in the cytoplasm, sometimes in the nucleus, consisting of a circumferential and central portion. If the sphere is cut by a plane passing through its center, the intersection of the plane and surface of the sphere is marked by a circle of minute bodies called microsomes from which astral rays extend. The central part has either a finely reticular structure and varies in dimensions according to the dividing activity of the cell or a radial structure proceeding from the central granules. The reticular structure may give place to the radial as the process of cell division with which the body is associated advances. In some cases the attraction sphere entirely disappears during cell division and hence it cannot be considered as an indispensable body.

Centrosome.—Within the attraction sphere is the centrosome which is composed of one, two or more granules. This body has the power to express its individual capacity by the properties of nutrition, growth, and reproduction and accordingly behaves in these respects as a permanent and essential part of the cell. When active it initiates the process of cell division and hence has been called the dynamic center of the cell. In this capacity it has been thought by some to be the vehicle which conveys a chemical substance which excites to activity the preliminary changes which start the process of cell division. But it is not always present and hence cannot be considered as the controlling cause of such an important act in cell life.

Plastids.—These small bodies appear in the cytoplasm and exhibit the properties of nutrition, growth and division like permanent structures. In embryonic cells they are small and colorless; but acquire new capacities as they develop in the growing cell. Some of them establish the process of chlorophyll formation and are called chloroplastids: others the process of starch formation and are called amyloplastids and still others, the process of pigment formation and are called chromoplastids. They seem to preside over the formation of coloring matters or pigments which have a fundamental importance in the vegetable kingdom.

Vacuoles.—These are spaces filled with a liquid and are most common in vegetable cells and in the protozoa. During the chemical changes taking place in metabolism small quantities of liquid may be produced which collect in spaces, thereby enlarging and forming small cavities or vacuoles. In some of the protozoa the vacuoles are contractile as though they had some part in the circulation of the nutritive liquids of the cell. In the higher animals the cells do not contain vacuoles except in pathological conditions.

Metaplasm.—During cell metabolism small bodies, granular in character and passive in behavior, appear in the meshes of the cytoplasm. These bodies are included in the term metaplasm: it is not known whether they are foods in reserve or waste matter. Cytoplasm then is a body having a fundamental structure which contains several other bodies dependent or independent, active or passive in character. Its wide departure from a homogeneous formation gives it a great range in function. It seems to be a coöperative society of individuals each one of which is engaged in the performance of a part for the better condition of the whole.

Nucleus.—The nucleus is a round or elongated body enclosed by the cytoplasm and presenting for consideration various structures. It makes a mass of protoplasm a cell. It takes charge of anabolism or the constructive side of metabolism. It makes continuation of the living cell possible. Cytoplasm is capable of katabolism only and is able to continue itself until its chemical elements are exhausted, when it ceases to belong to living matter. The nucleus is usually single, but in a certain few cells it is double. Increasing the number is very likely to change the function.

Nuclear Membrane.—This structure is a thin, delicate membrane surrounding the nucleus. It may or may not take a stain and for this reason it is thought that its derivation may vary—sometimes arising from the cytoplasm and sometimes from the chromatin. In the latter case it would be a true nuclear structure; while in the former it would not. Usually it disappears during the first stage of cell division by absorption of the chromatin and hence it may be considered in most cases as a part of it. It is always present in a resting cell and is evidently an indication of that condition. It forms the boundary between the formative and formed parts of the cell.

Chromatin.—This is the most important structure of the nucleus, since upon it depends cell division and continuation. Chemically it is composed of nucleinic acid and a proteid. Structurally it is composed of threads or granules. In a living condition it is not affected by ferments. It is called chromatin because it takes a stain and its staining capacity increases according to its activity. By its increasing amount under stimulation, its transverse and longitudinal cleavages, its behavior toward the centrosome and spindle, it becomes so arranged that its ultimate distribution into two equal parts is known as indirect cell division or karyokinesis. Its relation to the cell is such that by virtue of its chemistry it causes the element N to maintain its carbon association and thereby its potential position. According to some cytologists it has been transferred from parent to offspring, from generation to generation, through all the ages of living existences and hence has been the medium through which the characteristics of protoplasm are maintained.

Achromatin.—This is a colorless liquid without staining capacity, which occupies the spaces of the nuclear network. Little is known about it more than that it does not take a stain. It may be a nutritive liquid, a waste liquid or a supporting medium which, by its liquid condition, allows freedom of motion on the part of the chromatin during its activity.

Nucleolus.—A small, round or irregular body suspended in the nuclear network. There may be one or many or none in a nucleus. It does not seem to be necessary to the existence or continuation of any living part. Two varieties are described—one which stains like cytoplasm and the other like chromatin. The former is the true nucleolus while the latter are collections of chromatin. The real nature of the true nucleolus is unknown. Some regard it as a reserve fund of material which comes into use during nuclear activity. Others consider it as a product of chromatin activity.

Net Knots (*Chromatin Knots*).—These are small aggregations of chromatin produced by crossed chromatin threads; they have, therefore, the same function as chromatin.

Linin.—This is the fine reticular network which constitutes the supporting framework of the nucleus. It appears to resemble the meshwork of cytoplasm more than any other structure. It is somewhat granular in character and shows granules of different staining capacity. A difference in staining capacity indicates a chemical difference between bodies and this is often the only obtainable distinction between protoplasmic structures. The nucleus, therefore, is a collection of different materials enclosed by a membrane. The chief one of these is chromatin. As a body it presides over cell phenomena. The nuclear parts, plus the cytoplasmic parts, all acting in harmony constitute the cell which may be regarded as a community, the affairs of which are governed by small boards of administration.

CELL DIVISION OR REPRODUCTION.

All living cells, vegetable and animal, divide into two or more parts. This act is essential to their continuation; for if division did not occur at some time they would grow old and die. This remarkable behavior does not admit of explanation by itself. To say that cells divide from choice —inasmuch as the division is apparently a destructive process—is to grant an intelligence beyond that of the highest degree of the human mind. With all his courage and reasoning capabilities man, for example, would never dare to divide into two parts, if such an act were possible; for such a division would mean certain death to him. Such a tremendous process or act could only be the natural result of forces persistently at work in order to better the condition of the creature and not within the power of the individual. If cells remained the same in chemical mass they would remain the same in the exhibition of their phenomena and progress would become impossible; but they do not. Metabolism, by virtue of which chemical elements are constantly leaving cells and new chemical elements of the same kind but from a different source are constantly being added, produces an almost infinite series of variations and renders advance not only possible but actual. A cell cannot be precisely the same during any two successive periods of time, however short those periods may be, and if the chemical income exceeds the chemical outgo for any stated unit of time it will increase in mass and size. This is growth or the process by which a molecule of living matter adds to itself atomic groups of the same kind from the chemical substances of its environment and arranges them in forms like its own. As cells increase in size the relation of mass to surface will be changed and this upset in the ratio between mass and surface may cause division. As spherical bodies increase in size the cube of the mass is proportionate to the square of the surface; so that the volume increases much more rapidly than the surface. As chemical elements necessarily enter through the surface there comes a time when the central part receives less than the exterior and death follows: but just at this time division occurs, two smaller cells are produced and the ratio is restored to the normal. Cell division, then, is the certain result of growth and therefore a primitive and universal attribute of living matter. Cell division also limits the size of the cell and establishes the metazoa. The immediate cause of cell division is beyond detection. Chemical combinations and separations are invisible although an observer may be satisfied that they have occurred as he sees certain unmistakable results. The nuclei of cells show plainly that changes have taken place in the chromatin and cytoplasm during division and these changes present different phases of a continuous process which may be considered as a progressive molecular construction.

The cause of cell division must be attributed to the chemical elements added to the chromatin and these elements, apparently at least, do not always appear to have the same power. The particular form in which the added elements have existed seems to make some difference in the energy capacity of cell protoplasm. Of the two types of dividing cells which occur in the body, viz., tissue and germ cells, the germ cells exhibit the greatest capacity for energy inasmuch as they possess the original fund of force which is transmitted to all other cells by some fixed law of distribution. As tissue cells undergo metabolism the new chemical elements are derived from the chemical substances of their environment as—the proteids, carbohydrates, fats, salts and water; but somewhere in the anabolic side of the process a slight loss is sustained either on account of chemical changes in the protoplasmic mechanism or of variation in combining powers, and age or diminution of energy follows. The tendency on the part of tissue cells is toward a lowered capacity until death and decomposition take place and the old elements are brought into new, living forms again by the agency of sunlight. During the ascent of elements from the ashes of metabolism through vegetation to animal protoplasm and the rise of N from an ammonia group to a carbon group an increased energy capacity is obtained, so that death and decomposition are preparatory stages of a rejuvenated condition—the sun acting as the lifting power. But when the elements of the chromatin of a sperm cell are added to the similar elements of the chromatin of a germ cell the death, decomposition and solar agencies seem to be abridged and a rejuvenating result is accomplished in a short time through the agency of this union which is known as sexual. Sex, then, is the chief difference between senescence and rejuvenescence in cell life and is a substitute for the long process involved in the death, decomposition and solar agencies employed to rejuvenate protoplasm. This may be expressed in outline as follows:

Age.	Death, Decomposition.	Solar Agencies, Vegetation.	New Protoplasm.
Age.	Tendency toward Death and Decomposition.	Sexual union.	New Protoplasm.

If the chromatin of one tissue cell could be added to the chromatin of another, doubtless rejuvenescence would follow—but this is impossible and hence the long route through death to life. Any chemical body undergoing chemical action loses a part of its elements and likewise a certain amount of energy and neither its elements nor its energy can be reinstated without the help of some outside force. The protoplasmic molecule is very large and very complex and tends to run down. If one supposes that it contains 1,000 atoms and during its chemical actions it loses 100 of them the remaining molecule of 900 atoms would still be protoplasmic, but could not possess the same amount of energy as the original molecule of 1,000 atoms. Its phenomena would, also, be like the original but not the same. This is senescence and the fate of all living cells unless thwarted by sex.

VARIETIES OF CELL DIVISION.

1. Simple or direct division or amitosis.
2. Indirect division or mitosis or karyomitosis or karyokinesis.

The primitive form of division as seen in the protozoa is the simple or direct. This may occur as a binary fission, a spore formation or a budding process. Spore formation and budding are modifications of simple binary fission. Simple or binary fission consists of the separation of the cell into equal parts—the cleavage occurring in a longitudinal or transverse direction. It may occur in the active or cystic condition of the cell. The nucleus is slowly elongated, then becomes dumbbell in shape, then is constricted to a mere thread and finally breaks into parts, each one of which becomes the new nucleus of a new cell. Then the division of the surrounding protoplasm follows. This is the common method of division in all protozoa except the Sporozoa which divide by spore formation. But this is simple division modified rather than a distinct method of division. Some unicellular animals enclose themselves in a cystic envelope which is a means of defense against surrounding conditions unfavorable in their nature. In this state the nucleus may divide into two, four, eight, sixteen or more parts in the same manner as it does when in an active state. By a continuation of the process a vast number of parts may be produced each one of which is extremely small in its dimensions and is called a spore. Thus, the process involved in spore formation does not differ from that of fission but occurs a greater number of times within the enclosing capsule. In budding or gemmation a piece of the nucleus is pinched off from a certain part of the mother cell and becomes the nucleus of a new cell. If a vast number of buds are formed in this manner the result resembles that of spore formation. This is common among the Suctoria. Therefore it does not matter whether or not a cell divides by either of the above methods the process is essentially the same. From the fact that these modes of division are common among the earliest forms of animal life it may be inferred that they are the simplest modes of division, and yet there seems to be no adequate explanation of them because no visible changes are apparent in the chromatin in accordance with any recognized law. Cleavage does not indicate its cause by any visible act whatever and observation fails to detect the commencement of activity.

Indirect Cell Division or Karyokinesis or Karyomitosis.

This mode of division occurs in the majority of animal and plant cells especially of the higher orders. Much attention has been given to the relation of the centrosome to this form of division and the conclusion is that in those cases where it continues from cell to cell it may be considered as the vehicle of some chemical substance which initiates mitosis or chromatin activity. But it is not always present and karyokinesis does not seem to be affected by its absence. The present knowledge of this method of division is based upon the pictures produced by the chromatin activity of the nucleus. Since chromatin stains readily it may be observed from time to time and although the chemical changes escape detection their results may be seen in the arrangements of the chromatin. Having once begun, a continuous, progressive series of changes takes place in the chromatin until cleavage occurs when the process terminates and a reversal of the new chromatin products to a resting condition is apparent. If four persons stand on the bank of a flowing stream, each one five miles distant from his neighbor, and each one describes the scene before him, it is evident, that four different views would be presented while the same stream would be moving on through them all. So with the observers of karyokinesis. Different views are obtained according to the time and place of observation and these views are called the stages of the process. They are, perhaps, infinite in number, but are usually considered and described under four stages, viz., prophases, metaphases, anaphases and telophases, which may be examined under the following outline and in plate II.

Cell Division.

1. *Simple Direct Division or Amitosis.*—A primitive form of division common to the Protozoa. Probably binary fission occurs in the greatest number. Spore formation occurs in the sporozoa and budding or gemmation in the suctoria. This form of cell division is not well understood. Apparently the centrosome does not divide and takes no part in the process. Chromosomes are not formed by a transverse breakage of chromatin loops. The nuclear substance undergoes a division of its whole mass without apparent cause. This form of division occurs frequently in pathological growths and appears to indicate a retrogressive act. It is rare, if it occurs at all, in normal, physiological growths. If *spirogyra* be placed in water containing 0.5 % to 1 % of ether it divides rapidly by amitosis. If the same individuals be placed again in water they divide by mitosis: so that the character of the irritant causing the division governs the particular form of division which will follow.

Varieties: Binary Fission.—The nucleus slowly elongates, becomes dumb-bell in shape, then constricted to a thread and finally into two equal

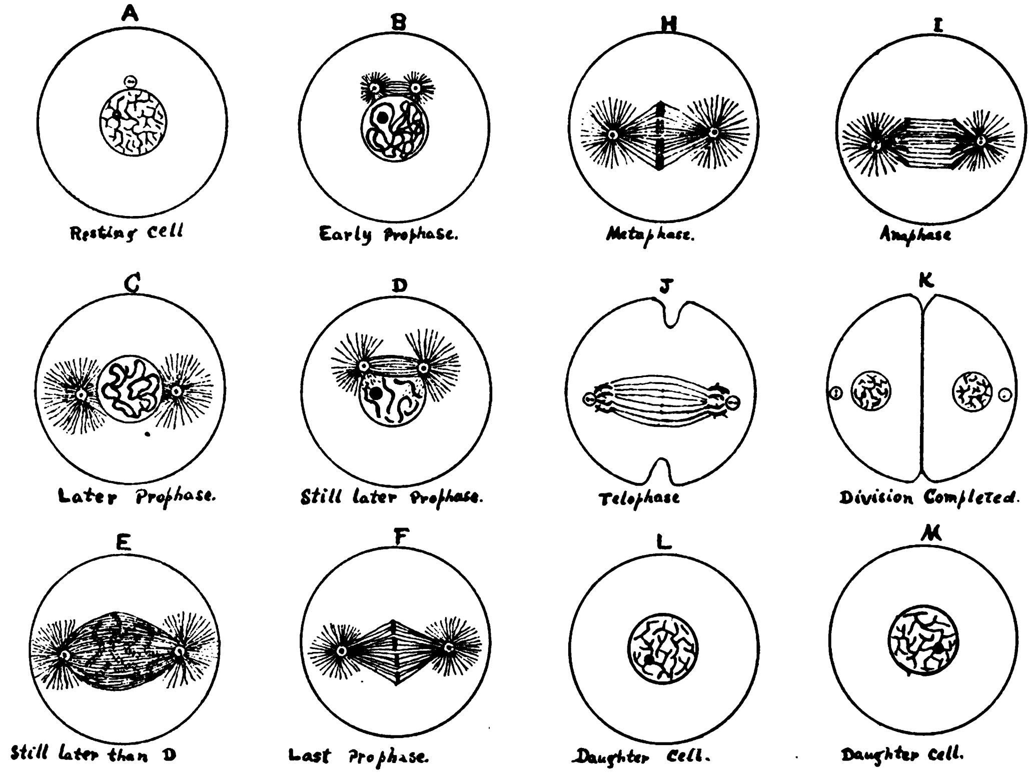


PLATE II.

DIAGRAMS OF MITOSIS (after Wilson).

parts each one of which becomes the new nucleus of the new cell. The division of the cytoplasm then follows and the division is completed.

Spore Formation.—The cell is enclosed in a cystic capsule and then the nucleus divides into a great number of very small parts each one of which is called a spore. These spores, by growth and development, become new cells.

Budding or Gemmation.—A piece of the nucleus is pinched off from a certain part of the mother cell and becomes the nucleus of the new cell.

2. *Indirect Division—Karyokinesis, Karyomitosis, Mitosis:*

Progressive Stages: Prophases, Plate II, figs. A, B, C, D, E, F. *Metaphases,* Plate II, fig. H. *Anaphases,* Plate II, fig. I. *Telophases,* Plate II, figs. J, K.

Prophases—Chromatic Changes.—The chromatin of the nucleus increases rapidly in staining power, loses its net-like arrangement, absorbs its nuclear membrane, resolves itself gradually into a convoluted thread or closed skein or spireme which then thickens and shortens to form an open skein or spireme or wreath which then divides transversely into a definite number of straight or curved rods called chromosomes. Each species of plant or animal has a fixed and characteristic number of chromosomes and in all forms of sexual reproduction that number is even. In sharks the number is 36. In gasteropods 32. In the mouse, lily, trout, salamander 24. In some worms 18. In the guinea pig, ox, onion, man 16. In the grasshopper 12. (Pl. II, figs. B, C, D.)

Prophases—Achromatic Changes.—The achromatin now becomes continuous with the cytoplasm. A fibrous spindle-shaped body appears, at either pole of which is a star or aster formed of rays of astral fibers radiating from a central point through the surrounding cytoplasm. In the center of each aster is the centrosome surrounded by a centrosphere. The centrosome divides into two similar halves, an aster forms around, each half, a spindle stretches between them and a body called the amphiaster is formed. The chromosomes become attached to the spindle which pulls them around its equator. This entire structure is known as the mitotic or karyokinetic figure. (Pl. II, figs. E, F.)

Metaphases—Chromatic Changes.—The chromatin net-work, which has been converted into a tangled thread and which is continuous in the form of a thread or discontinuous in the form of chromosomes, splits throughout its entire length into two exactly equal halves. (Pl. II, fig. H.) This is the most important step in the process of cell division.

Metaphases—Achromatic Changes.—The spindle exerts some control over the arrangement of the chromosomes since they are, with great regularity, distributed around its equator and along its meridians by virtue of some sort of attraction or mechanical connection. (Pl. II, fig. H.)

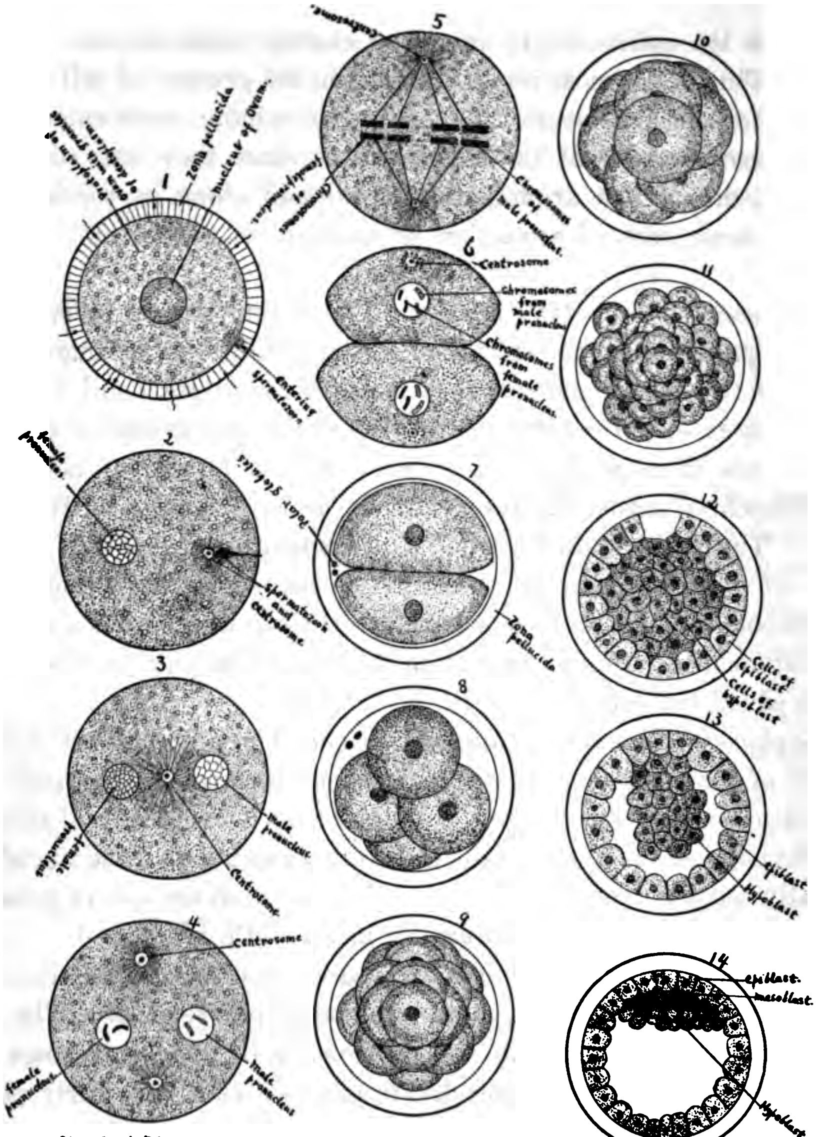
Anaphases—Chromatic Changes.—The chromosomes, in two equal groups, separate along the meridians of the spindle and become crowded together in two equal masses at the centers of the asters. (Pl. II, fig. I.)

Anaphases—Achromatic Changes.—As these two groups of daughter chromosomes diverge they are connected by a bundle of achromatic fibers stretching across the interval between them known as Interzonal Fibers. These fibers are regarded as a central spindle within an outer mantle of spindle fibers to which the chromosomes are attached and which become visible as they separate. During this period a series of deeply stained thickenings appear in the equatorial plane of the central spindle called the cell plate. (Pl. II, fig. H.)

Telophases—Chromatic Changes.—Each daughter nucleus receives one half of the spindle, one aster with its centrosome and an equal number of chromosomes and hence the daughter nuclei are of equal size; but if the division of the cytoplasm which follows is unequal the nuclei also gradually become unequal—a fact which shows that the size of a nucleus is governed by that of the cytoplasmic mass. (Pl. II, fig. J.)

Telophases—Achromatic Changes.—As a rule the spindle fibers disappear. A portion of them, however, sometimes remains. The aster may disappear together with the centrosome or the centrosome may persist outside the nucleus and divide into two at a very early period. Constriction and division of the cytoplasm follow and the process is completed. (Pl. II, figs. J, K.)

Retrogressive Changes.—Following the longitudinal cleavage of the chromosomes and their separation along the meridians of the spindle, a reversal of those changes, which led up to the cleavage, follows until the daughter nuclei show their chromatin in the resting condition of the cell. (Pl. II, figs. L, M.)



Figs. 1. 2. 3. 4. 5. 6. represent the process of fertilization.
(after Boveri)

Figs. 7. 8. 10. 9. 11. Stages of segmentation after fertilization. 12. 13. 14 stages in the formation of epiblast, hypoblast and mesoblast (after van Beneden)

PLATE III.

FERTILIZATION AND TISSUE GENESIS.

TISSUE GENESIS.

GERM CELLS.	CELL CHANGES.	FORMATIVE PROCESSES.		DIVISIONS OF THE BLASTODERM.	PARTS OF THE BODY DERIVED FROM T THREE DIVISIONS.	
1. Ovum. Plate V, Fig. 12.	Division of chromatin. Extrusion of polar globules. Loss of one half of the original number of chromosomes. Formation of female pronucleus.	Union of male and female pronuclei. Plate III, Figs. 1, 2, 3, 4.	Division of the new cell and formation of the blastoderm. Plate III, Figs. 5–11.	1. Ectoderm or Epiblast. Plate III, Fig. 12.		Epidermis and appendages. Secreting glands of the skin. Epithelium of the mouth, salivary gland nasal tract. Enamel of the teeth. Lens of the eye. Retina. Epithelium of the labyrinth of the ear. Epithelium of male urethra except pro part. The entire nervous system.
2. Spermatozoön. Plate V, Fig. 13.	Division of chromatin. Loss of one half of the original number of chromosomes. Formation of male pronucleus.			2. Mesoblast or Mesoderm. Plate III, Fig. 14.	1. Mesothelium.	Striped voluntary muscles. Striped involuntary muscles. Epithelium of serous membr Epithelium of genito-urinary tem, except bladder and ure
					2. Mesenchyme.	Connective tissues. Smooth muscle. Spleen, lymph nodes and e lium of blood, lymph vesse spaces.
					3. Mesamœboid.	Red and white blood cells.
				3. Hypoblast or Entoderm. Plate III, Fig. 13.		Epithelium of the thymus and thyroid. Epithelium of Eustachian tube and tympa Epithelium of the alimentary canal (mout cepted) and all the glands which open in Liver and pancreas. Epithelium of the respiratory tract and al glands which open into it. Epithelium of bladder and prostatic urethr

The animal body is a coöperative community of individual parts all of which have a community of interests. The investigation which leads one from a consideration of the whole to a consideration of the ultimate parts reveals the organization by which that community of interests is maintained. The chemical elements of protoplasm, the chemical actions of these elements during metabolism, the chemical constitution of the waste matters of metabolism make it necessary that the same chemical elements be supplied to protoplasm in order that it may continue itself. The systems by which these elements are prepared, supplied and removed are the great systems of the body. The digestive system, becomes a necessity because hydrations and solutions of substances containing the chemical elements of the body are essential; the respiratory system, because oxygen income and carbon dioxide outgo are essential; the circulatory system, because a circulating liquid with the chemical elements in solution is essential; the urinary system because the elimination of waste matters is essential; the genital system, because the continuation of the species is essential; the motor system, because change of location on the part of the animal and distribution of movable contents are essential; the systems of special sense, because the selection of food, protection of body and welfare of animal are essential; the central nervous system, because a central administration of community affairs is essential. All of these systems have been gradually evolved along the line of animal progress according to the requirements of animal mass. Systems, therefore, are collective assemblies whose united activities characterize the animal and express the phenomena of animal life. The individual parts which constitute the systems and which are responsible for their concerted activities are called organs.

Tissues.—The word "tissue" has been generally adopted and is understood to mean one of the four structural parts of which the body is composed. They are all composed of cells and intercellular substances and may be regarded as the building materials of the body and its various organs. For the most part there is difference enough between them to render their identification possible. Each tissue is found to occur in several forms known as varieties. The classification of the varieties is based upon the form which the cells and intercellular substances have assumed and generally there are sufficient differences between these varieties to enable one to recognize them. The four tissues, their varieties, descriptions, locations may be seen in the following outlines and plates.

EPITHELIAL TISSUE.

CLASSIFICATION.	VARIETIES.	DESCRIPTION.	LOCATION.
1. Simple.	1. Pavement, squamous, tesselated, scaly, endothelium. Plate IV, Figs. 1, 5.	One single layer of cells united by cement.	Blood vessels, serous membranes and lymphatics, air cells, mastoid cells, capsule of Bowman. Fifth ventricle of brain. Posterior surface of anterior capsule of crystalline lens.
	2. Cubical, columnar, cylindrical. Plate IV, Figs. 2, 3.	One single layer of cells united by cement.	Alimentary canal columnar from cardiac end of stomach to anus. Ducts.
	3. Ciliated. Plate IV, Fig. 4.	One single layer of cells united by cement.	Uterus, half of cervix uteri, Fallopian tube, ventricles of brain except the fifth, central canal of spinal cord.
2. Stratified.	1. Pavement, scaly, squamous, tesselated. Plate IV, Fig. 6.	Several layers of cells united by cement. Deeper cells are columnar and flatten out toward the surface.	Epidermis, mouth, tongue, vocal cords, epiglottis, œsophagus, cornea, olfactory part of the nasal mucosa, external auditory canal, lower half of cervix uteri, vagina, glans penis, anus, labia minora, female urethra, meatus urinarius of male urethra.
	2. Columnar. Plate IV, Fig. 7.	Several layers of cells united by cement. Deeper cells round or polygonal, becoming columnar when required.	Parts of vasa efferentia, coni vasculosi of testicle, pendulous male urethra and upper part of lachrymal duct, vas deferens except first part.
	3. Ciliated. Plate IV, Fig. 8.	Same cell arrangement as described above in the columnar type.	Lower part of lachrymal duct, respiratory part of nasal mucosa, Eustachian tube, larynx, trachea, bronchi, epididymis, first part of vas deferens.
3. Pseudo-stratified.	1. Columnar. Plate V, Fig. 14.	A single layer of cells with nuclei in different planes.	Vesiculæ seminales.
	2. Ciliated. Plate V, Fig. 14.	A single layer of ciliated cells with nuclei in different planes.	Osseous part of Eustachian tube, tympanum of ear.
4. Transitional.	1. Polygonal, pear-shaped cells. Plate IV, Fig. 9.	In the number of layers midway between the simple and stratified. Lower cells are pear-shaped and dovetail into concave upper cells.	Pelvis of kidney, ureters, bladder and prostatic portion of urethra.
5. Polygonal, polyhedral, glandular.	1. Cells of various types which vary from those of a columnar type to those of a scaly type.	Cells of no definite shape united by cement, supported by a basement membrane lining the acini of secreting glands and the tubular units of glandular structure.	Acini of secreting glands and tubular units of glandular structure.

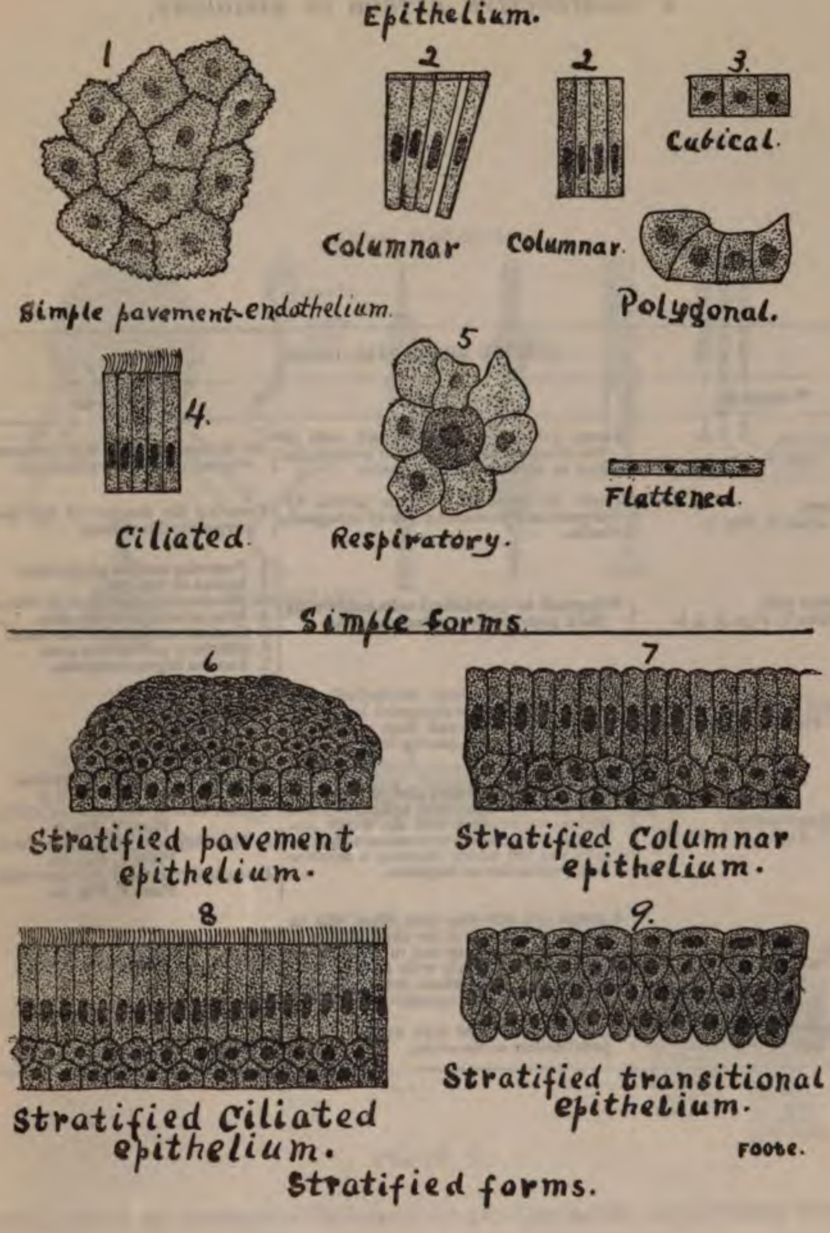

Epithelium.
1
2
2
3.
Cubical.
Columnar
Columnar.
Polygonal.
Simple pavement-endothelium.
5
4.
Flattened.
Ciliated.
Respiratory.
Simple forms.
6
7
Stratified pavement epithelium.
Stratified Columnar epithelium.
8
9.
Stratified transitional epithelium.
Stratified Ciliated epithelium.
FOOTE.
Stratified forms.

PLATE IV.

The Different Varieties of Epithelium.

SPECIAL EPITHELIAL CELLS.

VARIETIES.	DESCRIPTION.	LOCATION.
1. Goblet cells. Plate V, Fig. 1.	Large, goblet or chalice-shaped cells of the columnar type with clear protoplasm and an accumulation of mucus.	On surfaces covered with columnar or ciliated columnar epithelium.
2. Enamel. Plate V, Fig. 2.	Four- to six-sided columns united by cement and containing 98% of inorganic salts.	Covering the dentine of the teeth as perpendicular prisms.
3. Pigment cells. Plate V, Figs. 3, 4, 5.	Polygonal or polyhedral cells containing black pigment in varying amounts.	1. Posterior surface of the iris. 2. Retina of the eye. 3. Membranous labyrinth of the ear. 4. Rete mucosum of the skin. 5. Cortical substance of the hair. 6. Olfactory part of the nose. 7. Lamina supra choroidea.
4. Cells of crystalline lens. Plate V, Fig. 6.	A single row of short polyhedral cells which develop into elongated lens fibers united by cement and form a more or less perfect double convex lens.	Crystalline lens.
5. Neuro-epithelium. Plate V, Figs. 7, 8, 9, 10, 11.	Cells of various shapes and sizes placed between external stimuli and nerve fibers and so constructed that the nerve elements and epithelial elements are blended into one cell which becomes a receiver and transmitter of impulses.	1. Rods and cones of the retina. Plate V, Figs. 7, 8. 2. Hair cells of the organ of Corti. Plate V, Fig. 9. 3. Olfactory cells of the nasal fossa. Plate V, Fig. 10. 4. Gustatory cells of the taste buds. Plate V, Fig. 11.
6. Ovum. Plate V, Fig. 12.	A round cell differing from other cells in the equal division of its chromatin as it approaches maturity and in its capacity at that time to fuse with another cell, producing a third which develops under usual laws into the complete animal.	Graafian follicles of the ovary.
7. Spermatozoön. Plate V, Fig. 13.	A cell of the ciliated type with the same peculiarities as the ovum.	Testicle.

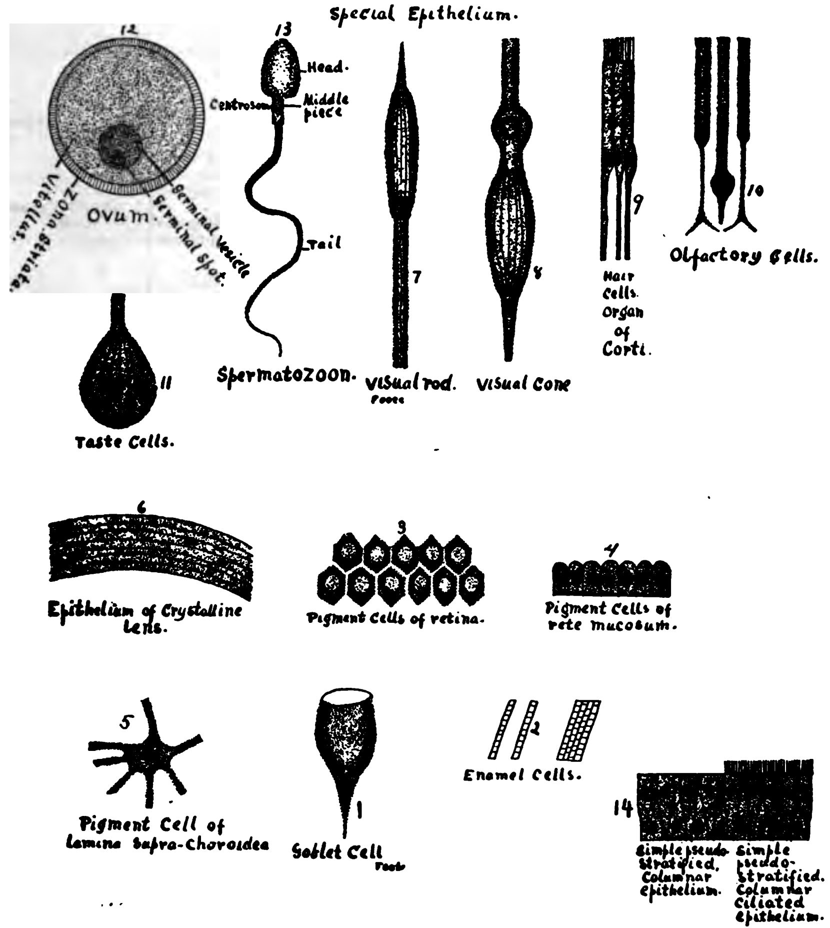


PLATE V.

SPECIAL FORMS OF EPITHELIUM OCCURRING IN THE GENERATIVE AND SENSORY SYSTEMS.

CONNECTIVE TISSUE.

Varieties.	Structure.	Description.	Location.
1. Lymph.	1. Cells. Plate VI, Fig. 5.	Small, colorless cells with large nuclei and small amount of protoplasm called lymphocytes, which may be antecedent forms of leucocytes.	1. Lymph spaces and vessels.
	2. Intercellular substance or plasma.	An intercellular liquid with the same composition as blood plasma except that the proteid constituents are less in amount.	
	Varieties.	**Description.**	
2. Specialized connective tissue cells.	1. Pigment. Plate VI, Fig. 9.	Round or oval granules of black or brown color packed together within the cells. They may escape and show the Brownian movement. Alone they are colorless. They may be excited to aggregation or separation by nerve stimuli giving shades of any density.	1. Outer surface of choroid. 2. In the iris. 3. On the pia mater of the upper part of spinal cord. 4. In retiform tissue of some lymph nodes. 5. Sometimes in the spleen.
	2. Osteoblasts. Plate VI, Fig. 14.	Flat cells with large nuclei and many branches. They are the bone-forming cells.	1. In the lacunæ of bone. 2. Beneath the periosteum.
	3. Osteoclasts. Plate VI, Fig. 15.	Large cells with many nuclei. They are the bone-absorbing cells.	In the irregular spaces of newly-made bone.
	4. Myeloplaxes. Plate VI, Fig. 16.	Large giant cells, not unlike the osteoclasts.	Bone marrow.
	5. Erythroblasts. Plate VI, Fig. 17.	Small red-tinted cells resembling nucleated red blood cells of the embryo.	Red bone marrow.
	6. Marrow cells. Plate VI, Fig. 18.	Cells like the leucocytes except that they have larger, clearer protoplasm and larger nuclei.	Bone marrow.
	7. Odontoblasts. Plate VI, Fig. 19.	Long columnar cells with long and delicate processes.	Pulp cavity of tooth on the dentinal surface.
	8. Phagocytes. Plate VI, Figs. 6, 7, 8.	Spherical, nucleated, amœboid cells which destroy other cell life by their digestive ability.	Anywhere.
	9. Neuroglia. Plate VI, Fig. 24.	Cells with many branches radiating from the protoplasm. Although from the epiblast their tumors are called histioid.	Supporting framework of nerve tissue.

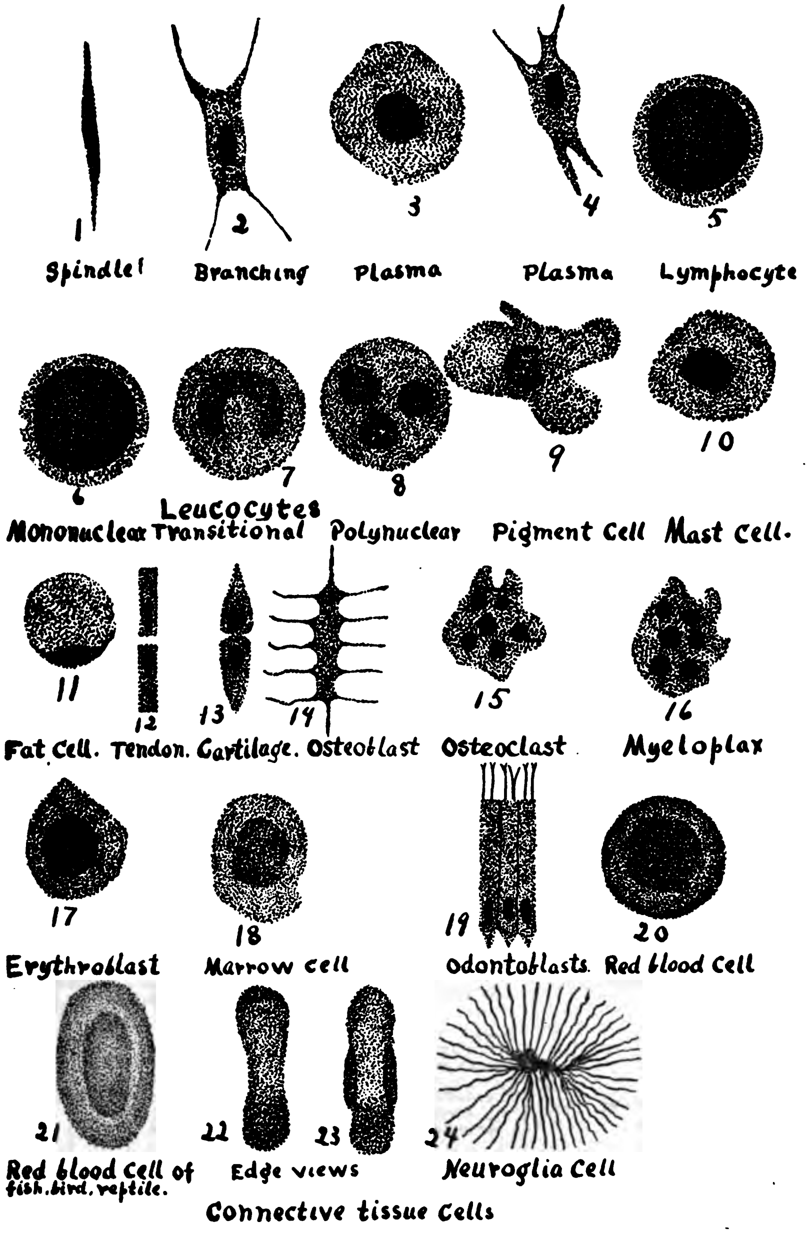

1 Spindle
2 Branching
3 Plasma
4 Plasma
5 Lymphocyte
6
7
Leucocytes
8
9
10
Mononuclear Transitional Polynuclear Pigment Cell Mast Cell.
11
12
13
14
15
16
Fat Cell. Tendon. Cartilage. Osteoblast Osteoclast Myeloplax
17
18
19
20
Erythroblast Marrow cell odontoblasts. Red blood Cell
21
22
23
24
Red blood Cell of fish, bird, reptile. Edge views Neuroglia Cell
Connective tissue Cells

PLATE VI.

THE VARIOUS FORMS OF CONNECTIVE TISSUE CELLS OCCURRING IN BLOOD, CONNECTIVE TISSUES AND NERVOUS SYSTEM.

CONNECTIVE TISSUE.

VARIETIES.	STRUCTURES.	DESCRIPTION.	OCCURS AS	LOCATION.
1. White Fibrous. Plate VII, Fig. 19.	1. Cells.	1. Irregular, Plate VI, Fig. 2. 2. Branching, Plate VI, Fig. 2. 3. Spindle, Plate VI, Fig. 1. 4. Plasma, 5. Leucocytes, Plate VI, Figs. 4–8. 6. Tendon, Plate VI, Fig. 12.	1. Tendons.	Attach muscles to bone.
			2. Ligaments.	Connect bones together forming joints.
	2. Intercellular Substance or Base.	Fine, wavy, parallel, non-anastomosing fibers which swell up with acetic acid and yield gelatin on boiling. Cement.	3. Membranes.	Periosteum, perichondrium, dura mater, pia mater, serous membranes, sclerotic coat of eye.
			4. Aponeuroses or Fascia.	Expansions which unite muscles.
2 Yellow Elastic. Plate VII, Fig. 20, 21.	1. Cells.	Flat, irregular in shape, often wrapped around the fibres.	1. Ligaments.	1. Ligamentum nuchae. 2. Ligamentum subflava.
			2. Membranes.	Fenestrated membranes of blood-vessels.
	2. Intercellular Substance or Base.	Large, anastomosing fibres which curl at the broken ends, do not swell up with acetic acid, do not yield gelatin on boiling; but do yield elastin if high temperature is prolonged. Cement.	3. Areolar Tissue.	Everywhere.
			4. Yellow Elastic Cartilage.	External ear, Eustachian tube, epiglottis and cornicula laryngis.

CONNECTIVE TISSUE.—*Continued.*

VARIETIES.	STRUCTURE.	DESCRIPTION.	LOCATION.
3. Areolar or cellular. Plate VII, Fig. 15.	A combination of white fibrous and yellow elastic tissues. Both varieties run in all directions and present the same structure as the separate tissues.	A soft, fleecy, supporting or a firm, dense uniting tissue of open or close texture according as free motion or firm connection of the parts supported or united is required. Wherever it is it is a tissue of spaces which have given it its name.	Forms the subcutaneous tissue, the subserous and submucous coats of serous and mucous membranes, the sheaths of muscles, blood vessels and nerves and connects organs and parts of organs. If all the organs were removed it would form a model of them all.
4. Mucous, embryonic or gelatinous. Plate VII, Fig. 16.	1. Cells. 2. Intercellular substance.	Round, branching or spindle according to the stage of advancement present. In round cell areas has no structure, in complete cell areas has the structure of fibrous tissue.	Found in umbilical cord of fœtus as Wharton's Jelly. Does not occur in the adult.
5. Lymphoid or adenoid, retiform or reticular. Plate VII, Figs. 17, 18.	1. Cells. 2. Intercellular substance.	Leucocytes or white blood cells or lymph cells in the meshes of the retiform structure. Cells with delicate, uniting branches which enclose spaces and form the framework of the tissue which is called reticular or retiform tissue. A lymphoid tissue then is a retiform or reticular packed with leucocytes.	Found at all the entrances to the body; beneath the mucous membrane of the pharynx, tonsils, tongue, œsophagus, stomach, in the solitary glands, Peyer's patches and villi of the small intestine, in the solitary glands of the large intestine, in the mucosa of the appendix, beneath the mucosa of the larynx, trachea, bronchi and uterus and in 750 lymph nodes.

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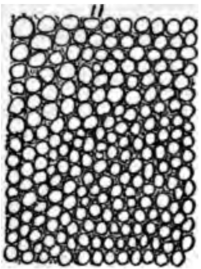
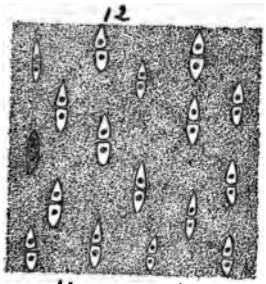


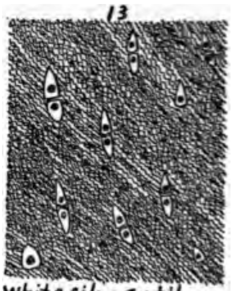
Adipose tissue.

12



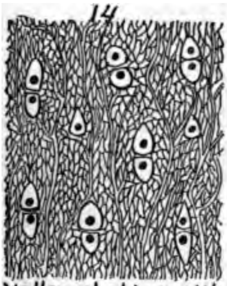
Hyaline Cartilage.

13



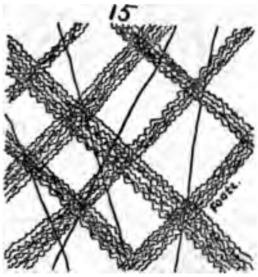
White fibro Cartilage.

14



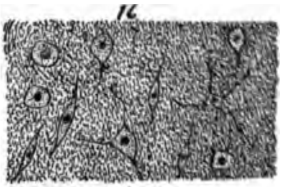
Yellow elastic Cartilage.

15



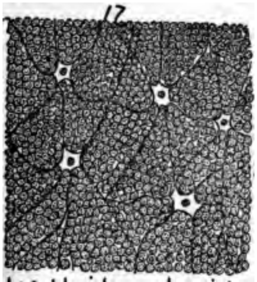
Areolar tissue.

16



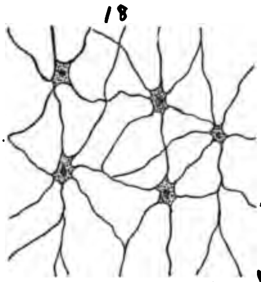
Mucous tissue.

17



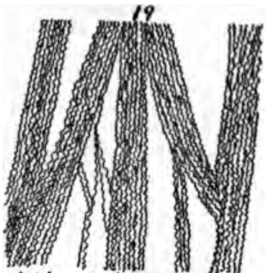
Lymphoid or adenoid tissue.

18



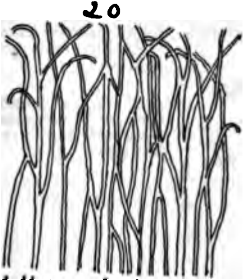
Retiform or reticular tissue.

19



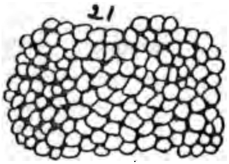
White fibrous tissue.

20



Yellow elastic tissue.

21



Cross section of yellow elastic tissue.

PLATE VII.

THE VARIETIES OF CONNECTIVE TISSUE.

CONNECTIVE TISSUE.—*Continued.*

Varieties.	Structure.		Description.	Location.
6. Adipose. Plate VII, Fig. 11.	1. Cells.		Consists of sacs filled with oil. The sacs are the remains of connective tissue cells whose protoplasm has been changed to oil with their nuclei to one side.	Found everywhere in the body except in the lungs, eyelids and penis and within the skull. Beneath the skin it forms with the areolar tissue the Panniculus adiposus.
	2. Intercellular substance.		Cement.	
7. Neuroglia. Plate VI, Fig. 24.	1. Cells.		Cells with many radiating branches which unite to form the framework for the support of nerve cells.	Found in nerve tissue as a support.
	2. Intercellular substance.		A modified form of connective tissue fibrillar substance.	
	Varieties.	Structure.	Description.	
8. Cartilage.	1. Hyaline. Plate VII, Fig. 12.	1. Cells.	Round, oval and encapsulated.	Makes up the thyroid, cricoid and arytenoid cartilages of the larynx, alæ of nose, rings of the trachea, plates of the bronchi, unites the ribs to the sternum and covers the joint surfaces of bones.
		2. Intercellular substance.	Without structure and looks like ground glass.	
	2. White fibro. Plate VII, Fig. 13.	1. Cells.	Same as the hyaline.	Makes up the circumferential cartilages of the hip and and shoulder joints, oval plates in the joints of the lower jaw and clavicle, sickle-shaped plate in the knee-joint, intervertebral disks, sesamoids and grooves of tendons.
		2. Intercellular substance.	A hyaline base containing fibers of white fibrous tissue.	
	3. Yellow elastic. Plate VI, Fig. 14.	1. Cells.	Same as the hyaline.	Makes up the foundation of the ear, Eustachian tube, epiglottis and cornicula laryngis.
		2. Intercellular substance.	A hyaline base mostly transformed to yellow elastic tissue.	

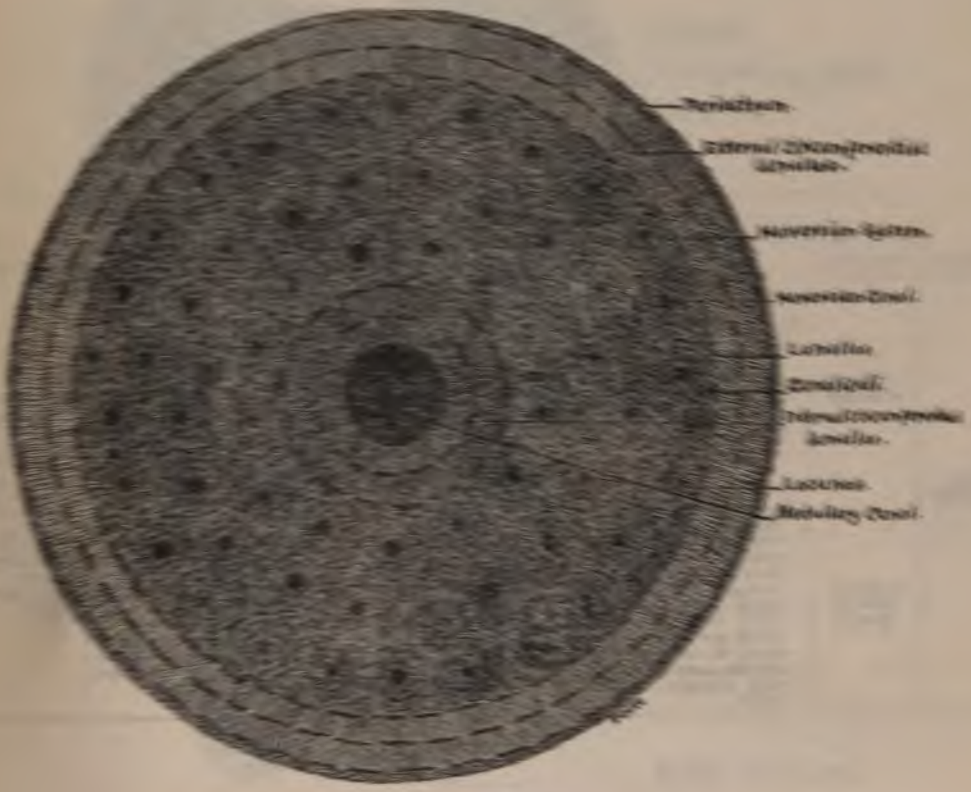


PLATE VIII.

CROSS SECTION OF AN ENTIRE BONE SHOWING MICROSCOPIC STRUCTURES.

CONNECTIVE TISSUE.—*Continued.*

	Two Sets.	Varieties.	Structure.	Description.	Chemistry.
Teeth. Plate IX.	1. Twenty temporary teeth. Ten in each jaw.	4. Two second molars Two first molars.	1. Membrane of Nasmyth.	Epithelial remains of the enamel organ covering the young enamel in the form of a thin membrane. It is soon worn off.	
		3. Two canines.	2. Enamel.	Prisms. Hexagonal columns extending from dentine to surface.	98% mineral matter. 2% animal matter.
				Lines of Retzius. Oblique lines passing through the enamel caused by periodic deposit of calcium salts.	
				Lines of Schräger. Parallel lines caused by differences in refraction.	
		2. Two lateral incisors.	3. Dentine.	Parallel fibers united by mineral cement extending from pulp cavity to enamel.	78% mineral matter.
		1. Two central incisors.	4. Dentinal tubules.	A system of minute, communicating canals, curving like the letter S, originating in the pulp cavity and ending in the interglobular spaces. They contain the prolongations of the odontoblasts, called dentinal fibers.	
	2. Thirty-two permanent teeth. Sixteen in each jaw.	8. Two wisdom.	5. Sheaths of Neumann.	Dense, mineral ground substance enclosing the dentinal canals.	
		7. Two second molars.	6. Interglobular spaces of Czermak.	Irregular, branching spaces in the dentine under the enamel where calcification has not occurred. When small and numerous they produce a granular appearance called granular layer of Tomes.	
		6. Two first molars.	7. Apical foramen.	Aperture at the end of the fang through which blood-vessels and nerves enter and emerge from the pulp cavity.	
		5. Two second bicuspids.	8. Cementum or crusta petrosa.	A bone structure, without Haversian canals, covering the fangs. It contains a great number of Sharpey's fibers uncalcified. Its lacunæ communicate with dentinal tubules.	
		4. Two first bicuspids.	9. Pulp cavity.	A central cavity occupied by connective tissue fibrils, branched connective tissue cells, a semi-liquid ground substance. At the surface is a layer of columnar cells — odontoblasts — which send two or more processes into the dentinal tubules and one into the pulp.	
		3. Two canines.	10. Peridental membrane.	A fibrous tissue membrane which is the periosteum of the alveolus, continuous with the cementum and blends with submucosa of gum.	
		2. Two lateral incisors.	11. Blood vessels. Lymphatics.	Blood-vessels enter by apical foramen, pass through pulp, divide into many branches which become fan-shaped, then extend into a capillary plexus which spreads out between the odontoblasts and dentine. Lymphatics have not been demonstrated in the pulp.	
		1. Two central incisors.	12. Nerves.	Some medullated nerves enter by the apical foramen, lose their sheaths, divide into fine fibers which form a plexus under the odontoblasts Other medullated fibers reach the outer part of the pulp, lose their sheaths and form a second plexus communicating with the first; from this small branches extend between the odontoblasts and into peridental membrane.	

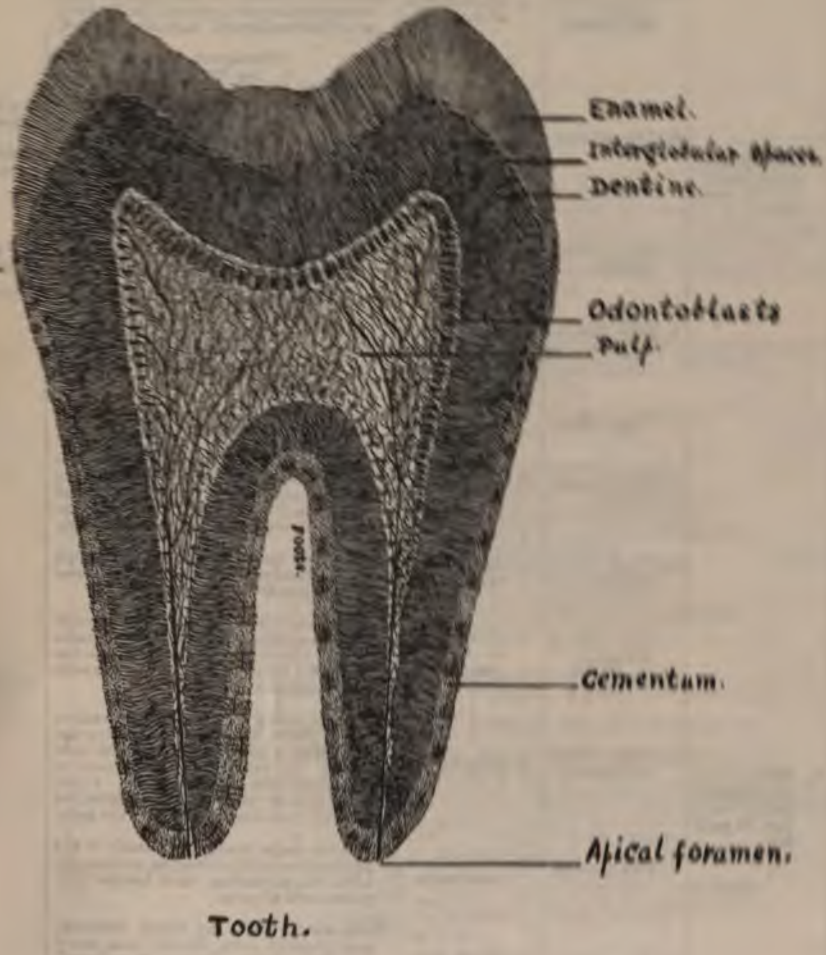


PLATE IX.

LONGITUDINAL SECTION OF A TOOTH SHOWING MICROSCOPIC STRUCTURES.

CONNECTIVE TISSUE.—*Continued.*

VARIETY.	STRUCTURE.	VARIETIES.	DIVISIONS.	DESCRIPTION.	VARIETIES.
12. Blood.	1. Cells.	1. Red.	1. Bird, fish or reptile. Plate VI, Figs. 21, 23.	Biconvex, nucleated, elliptical disks varying in size. The Petromizontidæ have the round cell.	
			2. Mammal and man. Plate VI, Figs. 20, 22.	Biconcave, non-nucleated, circular disks from 1/2700 to 1/12000 inch in diameter, composed of fatty pelicle or stroma within which is hæmoglobin. Camel tribe has the elliptical cell, 5,000,000 per cm.	
		2. White or leucocytes. Plate VI, Figs. 5, 6, 7, 8.	1. Bird, fish or reptile.	Spherical, amœboid, nucleated bodies of varying diameters, 1/5000–1/2500 inch.	Polynuclear neutrophiles, 70%. 2. Small lymphocytes, 20%. 3. Large lymphocytes, 2–4%. 4. Cells with an irregular-shaped nucleus, 2–4%. 5. Eosinophiles, 1–4%. Percentages vary.
			2. Mammal and man.	Same as above.	
		3. Blood platelets or third corpuscle or hæmatoblasts.	1. Bird, fish or reptile.	Small, discoid, amœboid oval bodies without color, 1/12500 inch.	
			2. Mammal and man.	Same as above.	
		STRUCTURE.	STRUCTURE.	DESCRIPTION.	
	2. Liquid intercellular substance or plasma or liquor sanguinis.	1. Fibrin.	1. Fibrinogen.	A globulin of the plasma obtained by half saturating plasma with sodium chloride.	
			2. Thrombin.	Produced by the combination of calcium salts, prothrombin and a ferment.	
			3. A lime salt.	Some salt of lime is necessary to formation of fibrin.	
		2. Serum.	1. Water.		
			2. Serum albumen and serum globulin.		
			3. Inorganic salts.		

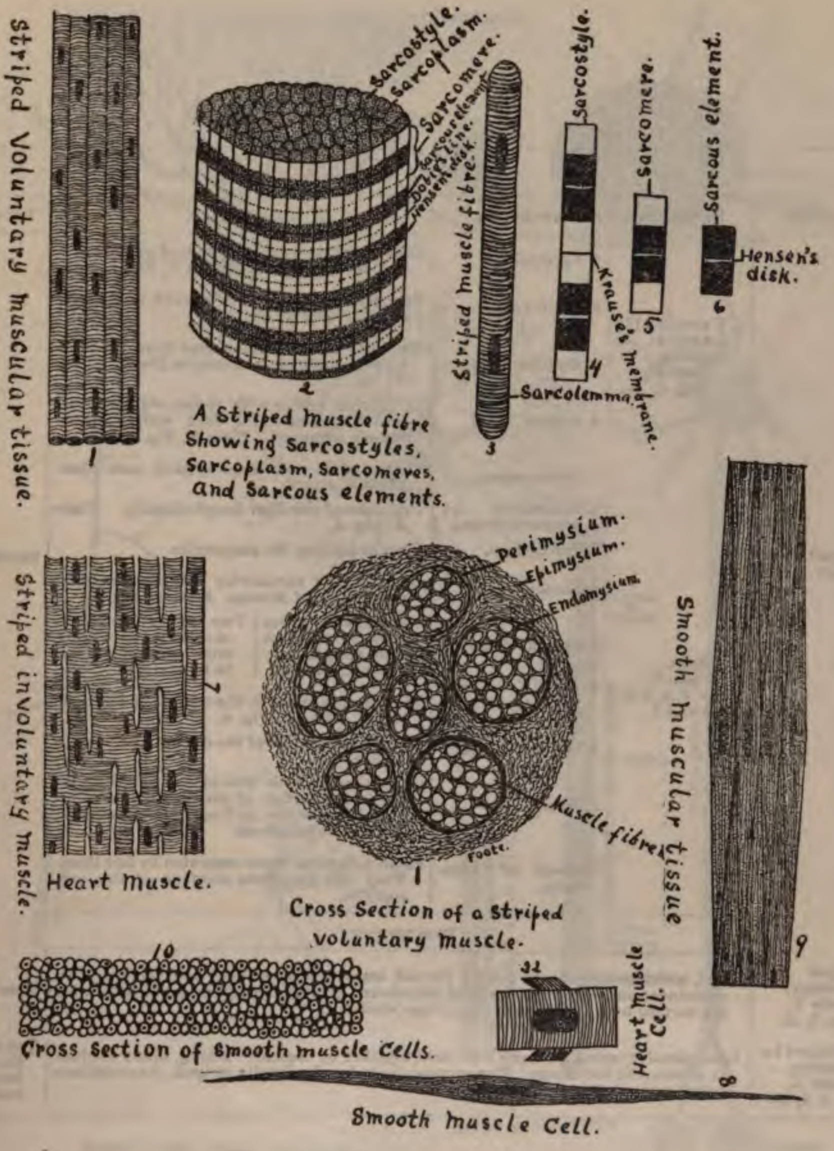


PLATE X.

VARIETIES OF MUSCLE.

MUSCULAR TISSUE.

Varieties.	Divisions.	Structure.	Description.	Location.
1. Striped Voluntary.	1. Fasciculi, Lacerti or Bundles. Plate X, Fig. 1.	1. Epimysium.	Connective tissue sheath around outside of a number of fasciculi. Plate X, Fig. 1.	Skeletal.
		2. Perimysium.	Connective tissue sheath around each fasciculus. Plate X, Fig. 1.	
		3. Endomysium.	Connective tissue extensions from the perimysium between the muscle fibers. Plate X, Fig. 1.	
		4. Fibers.	Cylindrical bodies with round edges and alternating light and dark stripes transversely arranged. Plate X, Fig. 1.	
	2. Fibers. Plate X, Figs. 2, 3, 4, 5, 6 and 1.	1. Sarcolemma.	Structureless membrane around each fiber. Plate X, Fig. 3.	
		2. Sarcostyles or muscle columns.	Divisions of the fiber longitudinally. Plate X, Fig. 4.	
		3. Sarcoplasm.	Cement uniting the sarcostyles.	
		4. Sarcomeres.	Parts of the sarcostyles between any two membranes of Krause. Plate X, Fig. 5.	
		5. Sarcous elements.	Parts of sarcomeres between any two light stripes. Plate X, Fig. 6. Two series of tubes, each series extending from Hensen's Disk to light stripe.	
		6. Dobie's Line, Krause membrane.	Line or membrane in the middle of the light stripe. Plate X, Fig. 4.	
		7. Hensen's Disk.	Line in the middle of the dark stripe. Plate X, Fig. 6.	
		8. Nuclei.	Oblong bodies with little or no protoplasm on the under surface of sarcolemma in mammals. In the fiber in frogs. Long series in the middle in insects.	
		9. Areas of Cohnheim.	Small polygonal areas separated by fine lines. They are the cross sections of the sarcostyles.	
			DESCRIPTION.	
2. Striped Involuntary. Plate X, Figs. 7, 22.			Short, anastomosing fibers faintly striped transversely, without sarcolemma, with prominent nuclei and longitudinal striations. Sections should be cut parallel with the surface in order to make the stripes visible.	Heart.
3. Unstriped Involuntary. Plate X, Figs. 8, 9, 10.			Long, slender, spindle-shaped cells held together by cement. A long, blunt nucleus is situated in the center. The protoplasm is longitudinally striped, the striations being continued into the nucleus.	The walls of the hollow viscera.

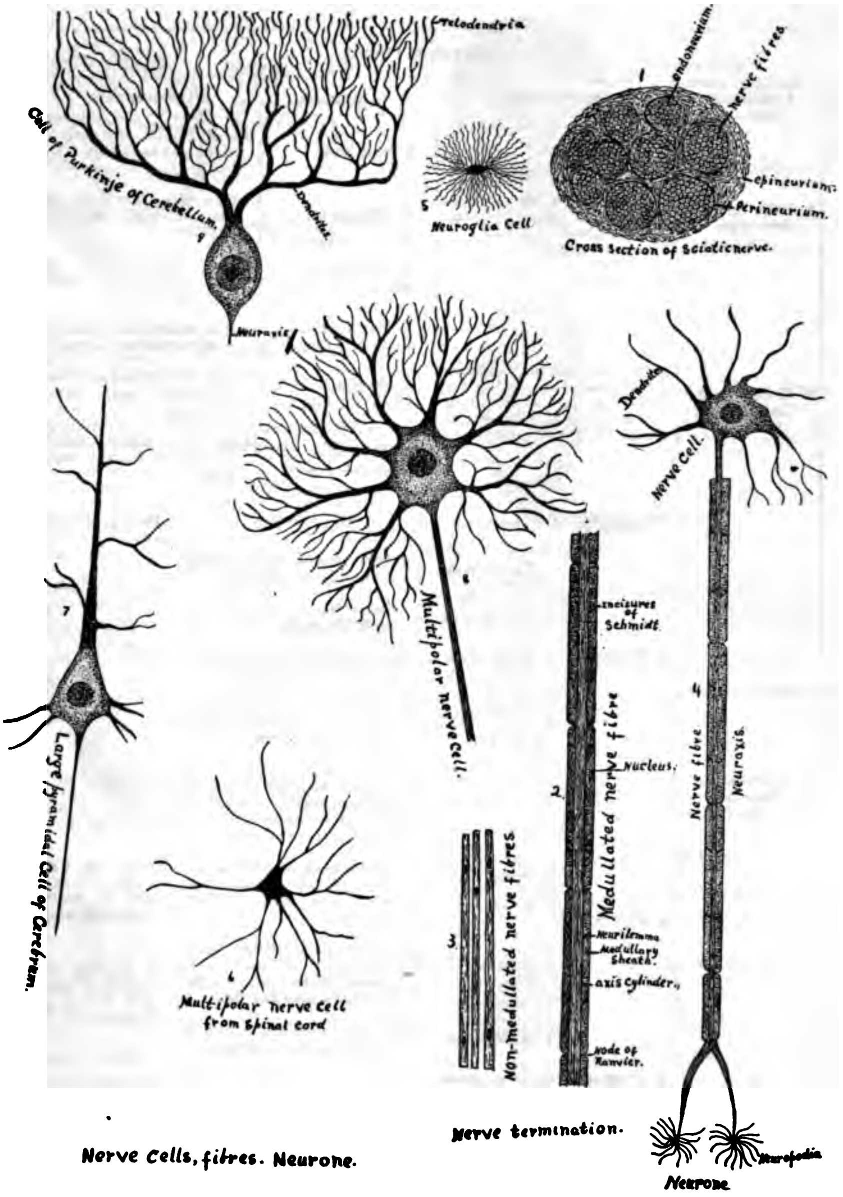


PLATE XI.

VARIOUS TYPES OF NERVE CELLS AND FIBERS. NEURON, NEUROGLIA,

NERVOUS TISSUE.

Divisions.	Varieties.	Description.	Varieties.	Description.	Location.
1. Gray matter or cells.	1. Cells of the first type.	Axis cylinders are continuous with those of the nerve fibers.	1. Spherical.	Large, round cells with nucleus and nucleolus. Unipolar.	Ganglia.
			2. Ellipsoidal.	Large, elongated cells with nucleus and nucleolus. Bipolar.	Spinal cord.
			3. Pyriform. Plate XI, Fig. 9.	Large, pear-shaped cells with nucleus and nucleolus. Multipolar.	Cerebellum.
			4. Pyramidal. Plate XI, Fig. 7.	Large, triangular cells with nucleus and nucleolus.	Cerebrum.
	2. Cells of the second type.	Axis cylinders do not leave the gray matter, but after dividing and subdividing envelope the other nerve cells in their vicinity.	5. Stellate. Plate XI, Fig. 8.	Large cells with nucleus and nucleolus and several branches.	Spinal cord.
			6. Neuroglia. Plate XI, Fig. 5.	Cells with many branches uniting to form a framework.	In any nerve tissue as a support.

Divisions.	Varieties.	Divisions.	Structure.	Description.	Peculiarities.	Location.
2. White matter or fibers.	1. Medullated. Plate XI, Fig. 2.	1. Funiculi.	1. Epineurium.	Areolar tissue surrounding a number of funiculi.		White matter of the brain and spinal cord and most of the cerebro-spinal nerves.
			2. Perineurium.	Areolar tissue surrounding each funiculus.		
			3. Endoneurium.	Extensions of perineurium between nerve fibers.		
			4. Fibers. Plate XI, Fig. 1.	Prolongations of nerve cells conveying impulses to and from nerve centers.		
		2. Fibers.	1. Neurilemma.	A thin, structureless, nucleated membrane inclosing the nerve. Absent in the white matter of the brain and spinal cord.	Constricted at intervals called nodes of Ranvier.	
			2. White substance of Schwann.	A framework of neurokeratin in the meshes of which is an oily matter called myelin.	Absent at both ends of nerve and at regular intervals, nodes.	
			3. Axis cylinder.	Central, conducting part-extension of the cytoplasm of the nerve cell. Divisible into fibrillæ.	An unusual pseudopodial extension of cell protoplasm.	
			4. Axolemma.	Delicate membrane surrounding axis cylinder.		
	2. Non-medullated. Plate XI, Fig. 3.	1. Funiculi.	Same as above.			Chiefly in the sympathetic system.
		2. Fibers.	1. Neurilemma.	Not known to exist.	A modification of the same sheath above described.	
			2. Axis cylinders.	Fibrillar plan more marked than in the medullated. The nuclei are embedded in the outer part of the cylinder.	The number of nuclei embedded in the outer part.	

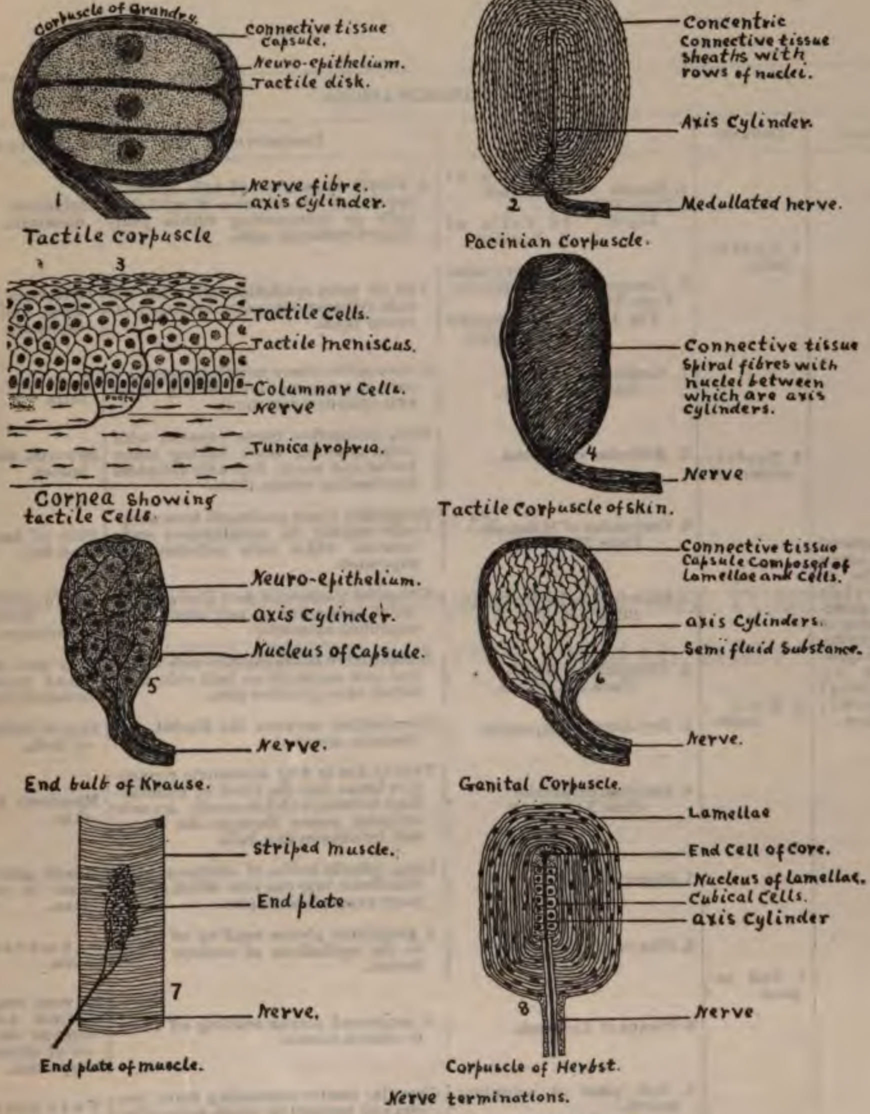


PLATE XII.

THE VARIOUS FORMS OF NERVE TERMINATIONS.

SECTION 2

CONSTRUCTIVE METHOD BASED UPON THE TUBE PLAN OF STRUCTURE OF THE ANIMAL BODY

NERVE TERMINATIONS.

PLAN.	ORGANS.	VARIETIES.		DESCRIPTION.	LOCATION.
The general plan seems to be to provide the greatest area of axis cylinder expansion by the most economic method.	1. Tactile cells.	1. Simple. Plate XII, Fig. 3.	1. Cells of Merkel. 2. Cells of Ranvier.	A simple expansion of axis cylinder applied to the surfaces of epithelial cells or terminating within pear-shaped epithelial cells.	Epidermis of mammals.
		2. Compound. Plate XII, Fig. 1.	1. Corpuscles of Grandry. 2. Corpuscles of Merkel.	Two or more epithelial cells with the axis cylinder expansion arranged between them.	Epidermis of birds and of mammals.
	2. Tactile corpuscles.	1. Genital corpuscles. Plate XII, Fig. 6.		A connective tissue capsule inclosing a core of polygonal cells among which axis cylinders terminate.	Penis and clitoris.
		2. Articular corpuscles.		Oval, connective tissue capsules with large granular cores having many nuclei and one to four axis cylinders terminating within them.	Synovial membranes.
		3. Corpuscles of Meissner. Plate XII, Fig. 4.		Connective tissue prolonged from a capsule spirally in membranous septa between which axis cylinders are expanded.	Skin of hands and feet.
	3. End bulbs.	1. Spherical and cylindrical. Plate XII, Fig. 5.		Elongated corpuscles into the center of which axis cylinders pass to end in an expanded extremity.	Conjunctiva and mucous membranes.
		2. Corpuscles of Herbst. Plate XII, Fig. 8.		A connective tissue capsule with a central core nucleated on both sides into which axis cylinders pass.	Skin and mucous membranes of birds.
		3. Key-Retzius corpuscles.		Intermediate between the Herbst and Pacinian corpuscles.	Skin of the bills of birds.
		4. Pacinian corpuscles Plate XII, Fig. 2.		Twenty-five to fifty concentric connective tissue lamellæ lined by endothelium between which is serum. An axis cylinder passes through the center and terminates in a bulb.	Mesentery and skin.
	4. End organs.	1. Organ of Golgi.		Long, spindle bodies of tendinous bundles fused into one into which one or more axis cylinders pass.	Muscle attachment to tendons.
		2. Plexus of Meissner.		A gangliated plexus sending off fibers to the epithelium of mucous membranes.	Submucous coats.
		3. Plexus of Auerbach.		A gangliated plexus sending off fibers to smooth muscle.	Between longitudinal and circular muscle of alimentary canal.
		4. End plate of voluntary muscle. Plate XII, Fig. 7.		Granular matter containing many nuclei and nucleoli in which axis cylinders are embedded.	Voluntary muscle.

SECTION 2

CONSTRUCTIVE METHOD BASED UPON THE TUBE PLAN OF STRUCTURE OF THE ANIMAL BODY

THE TUBE AS A STRUCTURAL AND FUNCTIONAL UNIT.

From simple observation of the animal body and its various organs in their natural positions it is evident that the tube forms a considerable part of them all. Reference to systems and organs, in italics, in the outline on pages 4 and 5, shows that most of them are tubes. Gross anatomy deals with visible structures such as the alimentary canal, body cavities, trachea, large and small bronchi, arteries, veins and lymphatics, ureters and bladder, uterus, Fallopian tubes, vagina, urethra, vas deferens, etc., and all are tubes of varying diameters and lengths. Minute anatomy deals with invisible structures such as the acini of secreting glands, alveoli of the lungs, tubes of the kidney and testicles, blood and lymph capillaries, etc., and these are very small tubes of microscopic sizes. Consequently whatever observation one makes, gross or microscopic, he is always dealing with tubes, large or small. The tube then is common to the greatest number of organs and is therefore a necessary part of them as a unit of structure. The development of the vertebrate kingdom from primitive forms of life also directs attention to this fact. The small dimensions of the Protozoa enable them to continue themselves and exhibit their phenomena of life without the presence of a central cavity; but, as physiological division of labor advanced in accordance with an increase of animal mass, a time came when a central cavity was necessary for the nutrition of the animal and from that time the tube became the basis of animal structure. It was foreshadowed as far back as *Euglena viridis,* a single-celled organism in which there was a slight indentation in the anterior end of the creature and which was set aside as a food tube of entrance to the small body. This simple tube in the low forms of life, developing into a complex system in the higher and highest forms, indicates the line of ascent along which animal progress has made its way. The worm, tunicate, fish, amphibian, reptile, bird and mammal—chief divisions of the animal kingdom—all present the tube as a common, fundamental structure of the body and of most of its viscera. Embryological development also reveals the tube in all its phases. After fertilization has occurred and the blastoderm has been formed the whole period of prenatal life is concerned with tube formations and adjustments and when the creature is born it is born as a large tube within which are arranged, in the form of viscera, a vast number of small tubes of all magnitudes—the kind of tube produced depending upon the functional requirements of the animal.

A definite structure as universally present in body formations as the tube must have a functional capacity equal in variety and importance to the structural; for the phenomena of animal life are the complex, constant results of chemical action taking place in the fundamental structures of the body. In as much as the basic tube presents such a variety of forms, it follows that it will also present a variety of functions proportionate to the character of the structural changes. We find, therefore, that tubes exhibit such functions as digestion, respiration, absorption, circulation, secretion, excretion, reproduction, progressive and intermittent motion of contents—all of which depend upon their structural variations. Since the animal first started as a simple, single tube it has not changed except in the number of tubes and the complexity of their arrangement. Metabolism, growth, motion and reproduction have always been the essential attributes of life, and they have been possible only on account of the tube activities of the body. The tube supply is the natural outcome of cell demand. For example, nutrition is absolutely essential to cell continuation and therefore must be provided for. Foods, by which it is maintained, are, as a rule, not adapted to cell metabolism until they have been subjected to certain chemical processes. These processes are made possible by the concerted actions of many tubular systems such as the respiratory, digestive, absorptive, circulatory and excretory. Whenever or wherever liquids, gases or solids are to be produced and directed to some definite point the tube is a self-evident structure.

Plan of Tube Arrangement.—The body is a large tube containing a prodigious number of small tubes which vary in diameters and lengths according to their functions. Some tubes are microscopic, others macroscopic; but the plan of their arrangement is the same everywhere. The microscopic tubes are joined by connective tissue to form the principal viscera while the macroscopic tubes form the avenues of income and outgo for these viscera. Simple dissection determines that most of the great systems of the body conform to this plan, as for example—the respiratory, digestive, urinary, genital and vascular. The respiratory system is composed of enormous aggregations of alveoli or small tubes joined by connective tissue to form the lobules and lobes of the lungs and of the small, medium and large bronchi, trachea and larynx which are large tubes of outgo and income for the gaseous products of metabolism and chemical elements of nutrition. The digestive system is composed of vast numbers of small, tubular secreting glands united by connective tissue to form the functional part, while the alimentary canal as a whole is a large tube providing for the income of foods, their digestion and absorption, and the outgo of waste. The urinary system is composed of myriads of small tubes united by connective tissue to form the kidneys, and of the pelvis, ureters, bladder and urethra which are large outgoing avenues of escape for the urinary products. The genital system is composed of a large number of small tubes which united by connective tissue, form the testicles or ovaries and of the vasa efferentia, epididymis, vas deferens, seminal vesicles, and ejaculatory ducts or Fallopian tubes, uterus and vagina which are the large tubes of exit from those organs. The vascular system is composed of tubes of various dimensions which form a complete circuit in the body—the small capillaries being the seat of nutritive processes, the large arteries and veins forming the avenues of income and outgo which render those processes possible. The secretory system is composed of enormous collections of small tubes—the acini—united by connective tissue to form the glands and of the outgoing ducts which are large tubes of escape for the various secretions. Thus the viscera are all formed according to the same plan of arrangement and economy of space, protection of delicate parts, certainty of action and successful operation are secured by this arrangement.

Formation of Tubes.—While analysis makes us familiar with parts of which tubes are composed, if the process of investigation terminates with the separation and identification of those parts, we have a knowledge which is useful but imperfect. Synthesis of the parts is essential to complete that knowledge and afford us a proper conception of the whole structure which can not be obtained by mere application of the analytical

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method. If we have discovered that all organs are composed of tissues and have not attempted to construct those organs by means of those tissues, we simply have discovered a collection of materials which are without purpose or significance. There are four tissues in the body; epithelial, muscular, connective and nervous, and each tissue is divided into several varieties. The varieties are the "building materials" and present fixed peculiarities which give to them important values both in chemical and mechanical constructions. They are combined in many ways according always to design, and tubes are constructed the walls of which are usually described as composed of coats. The coats are composed of layers and the layers of tissues. A coat or layer is known or determined by its predominating tissue, although, strictly speaking, almost any coat may contain all four tissues. Thus, by a connective tissue coat is understood a coat in which connective tissue can be seen as the *characteristic* tissue. Muscular coats may have several layers and different varieties of muscle but muscular tissue is the *predominating* tissue. Epithelial coats may have several varieties of epithelial cells, may include a connective tissue base and possess some kind of muscle, but epithelium gives to it its importance and hence *characterizes* it. In the formation of tubes from tissues we may begin with the simplest form which occurs in the body, viz: the one layer tube, an example of which is the capillary and by a process of tissue addition arrive structurally and functionally at the most complex variety which may be seen in the four coated tube, an example of which is the alimentary canal. The one layer tube is composed of one, single layer of pavement epithelial cells united by cement and is the simplest cell structure in the body; while the four coated tube has nearly all the tissues and many of their varieties. Between these two extremes of structure occur other tubes of varying thicknesses depending upon the tissues present. For convenience they are named according to their structural composition as: one layer, one coated, two coated, three coated and four coated tubes. See Plate XII*a*. Having some knowledge of tissues—their structure and purpose—it is only necessary to employ them as building units in order to construct any class of tube which may be desired. A one layer tube is always composed of one layer of cells and tissue additions are made according to the demands in each case and in no instance is anything more added than is needed to adapt the tube to the office which it has to perform. In as much as there are many varieties of tissues, perhaps twenty or more, all of which seem to have different purposes, it is evident that a constructed tube will exhibit many functions. The tissues and their varieties are represented in the following seven plates. They are in the form of layers and coats which are curved. Visceral tissues are for the most part

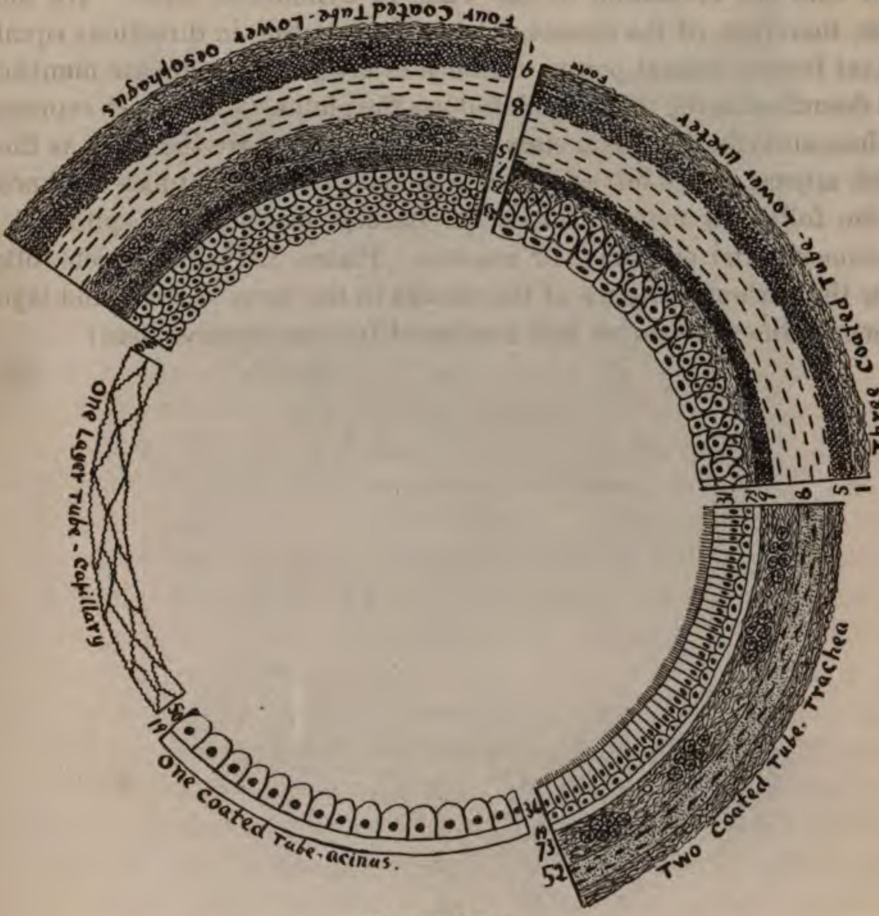

Four Coated Tube-Lower Oesophagus
1
9
8
15
7
Three Coated Tube-Lower Ureter
1
5
8
Two Coated Tube. Trachea
34
73
52
One Coated Tube-acinus.
19
56
One Layer Tube - Capillary

PLATE XII a.

Diagram Showing the Construction of the Five Classes of Tubes by Tissue Additions.

Taking as a foundation the one layer tube, which is purely an epithelial tube, and adding to the outside a basement membrane, then a connective tissue base, then a muscular coat, then a muscularis mucosæ, and all the tube classes with their component tubes may be constructed.

arranged in circular form on account of the tubular character of their structural units. Most all of the epithelial, muscular, connective and nervous tissues of viscera are therefore situated on curved surfaces or enter into the formation of the walls of cylindrical tubes. We must think, therefore, of the tissues as always extending in directions equally distant from a central point. Tissues in layers and coats are numbered and described in the table which follows the plates. The colors represent the hæmatoxylin and eosin stains and the numbers are the same as those which appear at the left of the case models. Coats of tubes are known by the following names: connective tissue, muscular, sub-epithelial or sub-mucous and epithelial or mucous. Plates XIII–XX which follow show the various varieties of the tissues in the form of coats and layers drawn on the same curve and numbered for constructive uses:

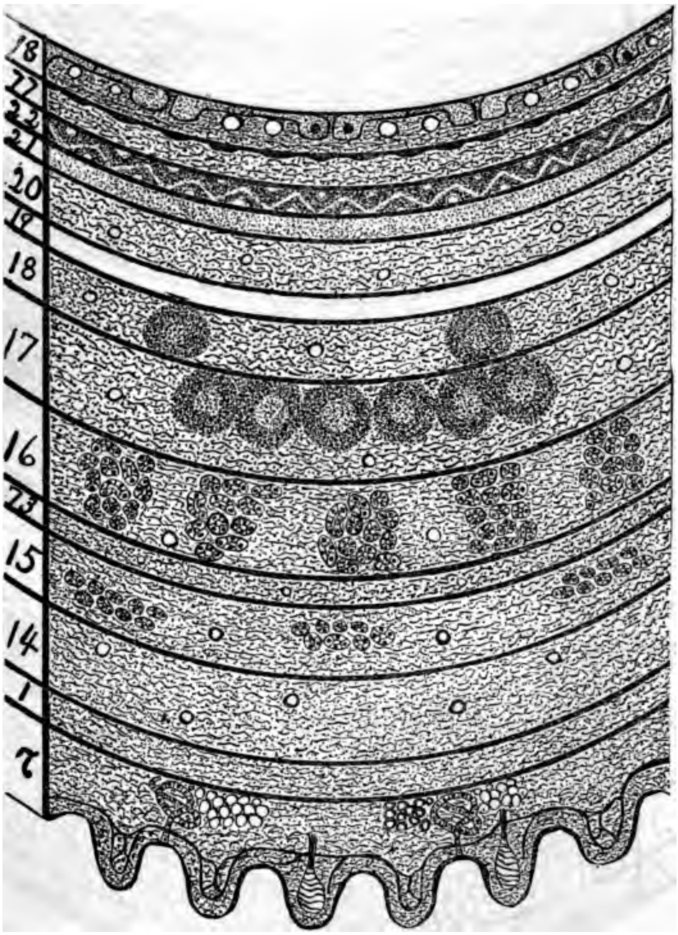


PLATE XIII.

Connective Tissues as Outside Coats, Sub-epithelial Coats with or without Secreting Glands, Peyer's Patches, Solitary Glands and Bases of Epithelial Coats for the Construction of Tubular Organs.

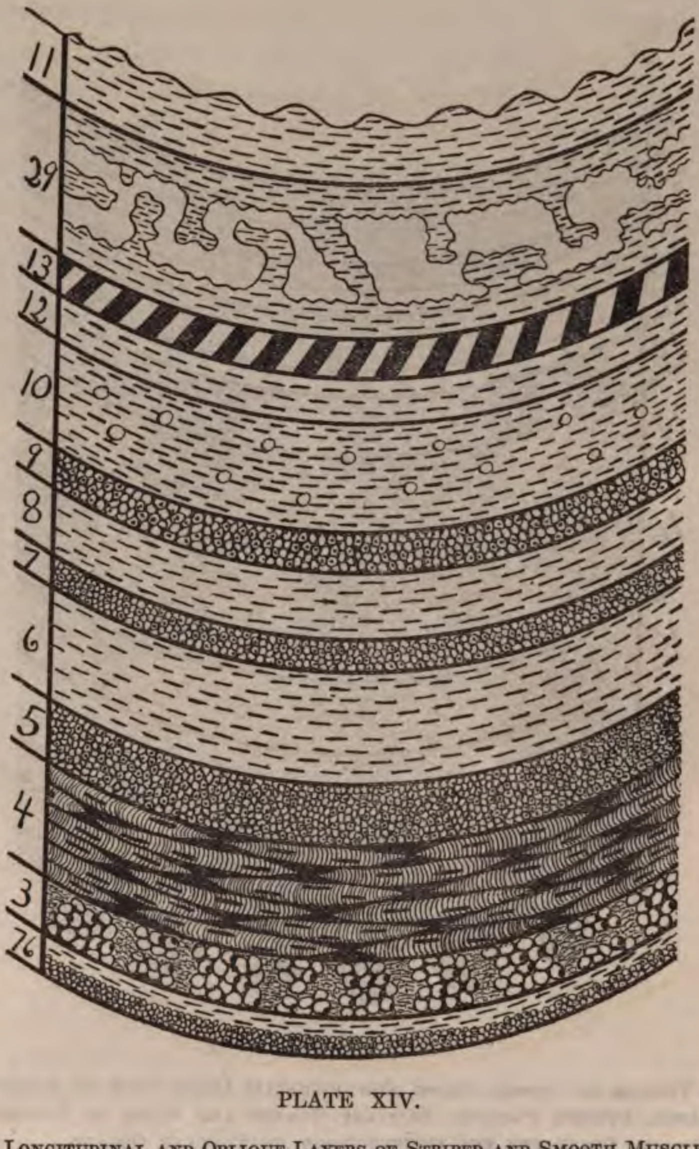


PLATE XIV.

Transverse, Longitudinal and Oblique Layers of Striped and Smooth Muscle, Thick and Thin, for the Construction of the Muscular Coats of Tubular Organs.

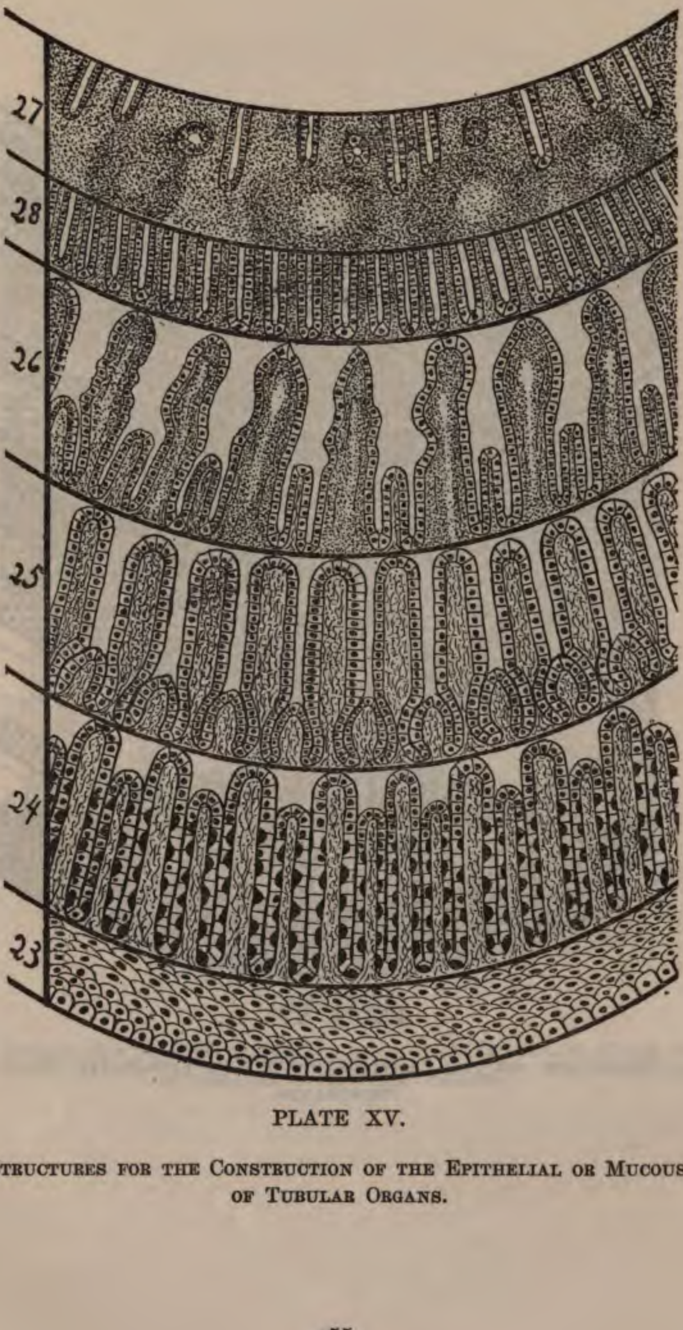


PLATE XV.

EPITHELIAL STRUCTURES FOR THE CONSTRUCTION OF THE EPITHELIAL OR MUCOUS MEMBRANES OF TUBULAR ORGANS.

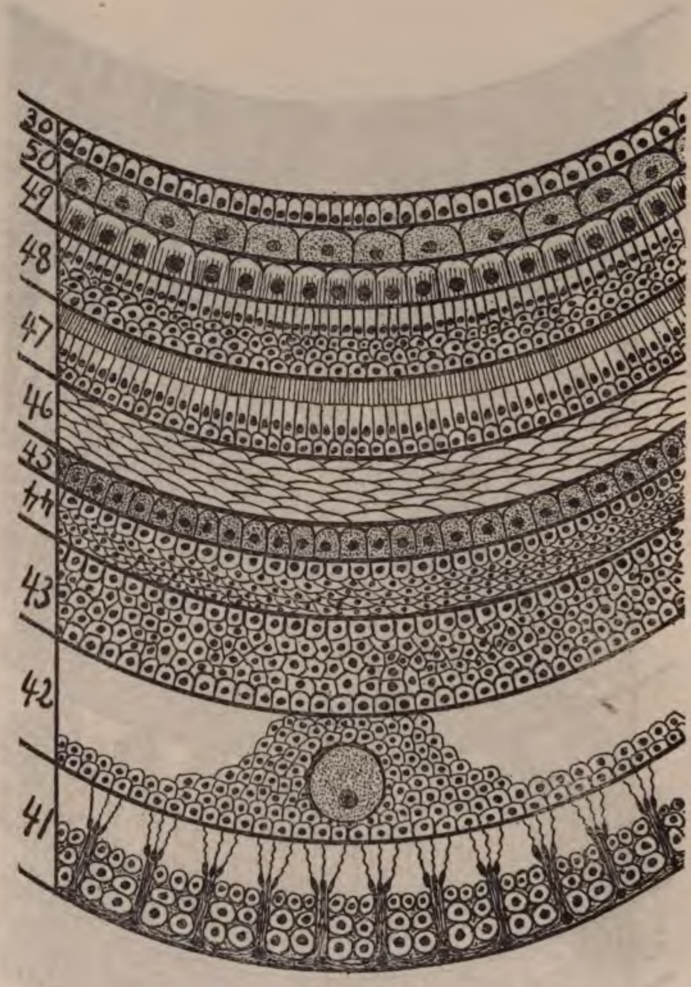


PLATE XVI.

EPITHELIAL STRUCTURES FOR THE CONSTRUCTION OF THE EPITHELIAL COATS OF MUCOUS MEMBRANES.

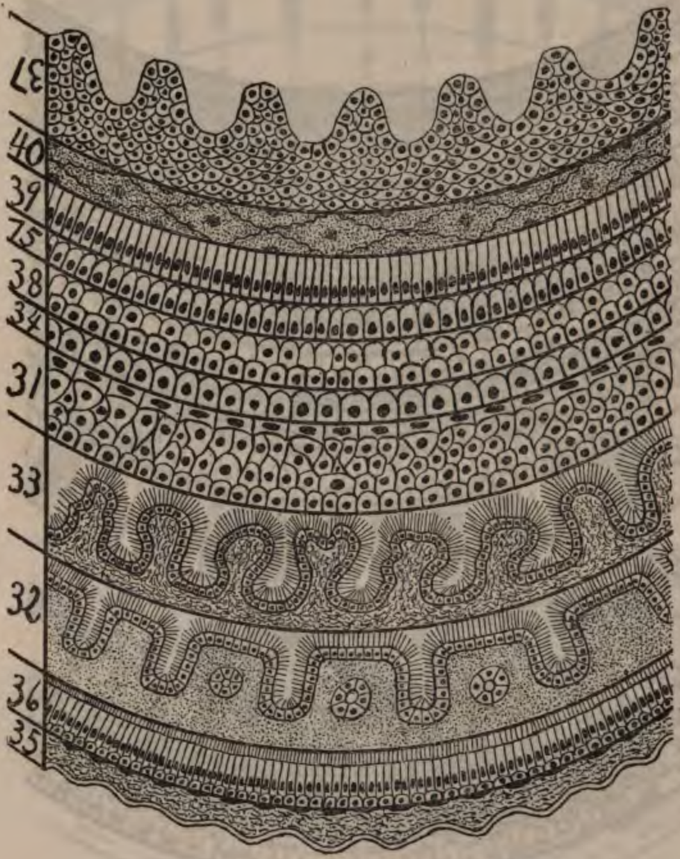


PLATE XVII.

EPITHELIAL STRUCTURES FOR THE CONSTRUCTION OF THE EPITHELIAL COATS OR MUCOUS MEMBRANES OF TUBULAR ORGANS.

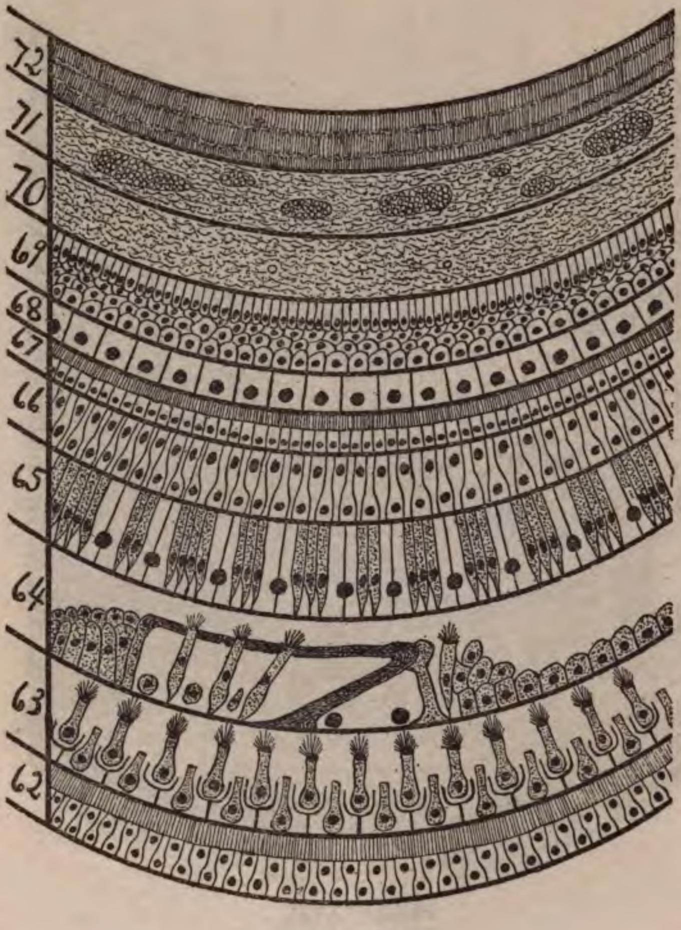


PLATE XVIII.

Connective Tissue, Epithelial and Neuro-epithelial Structures for the Construction of Certain Coats of Tubular Organs.

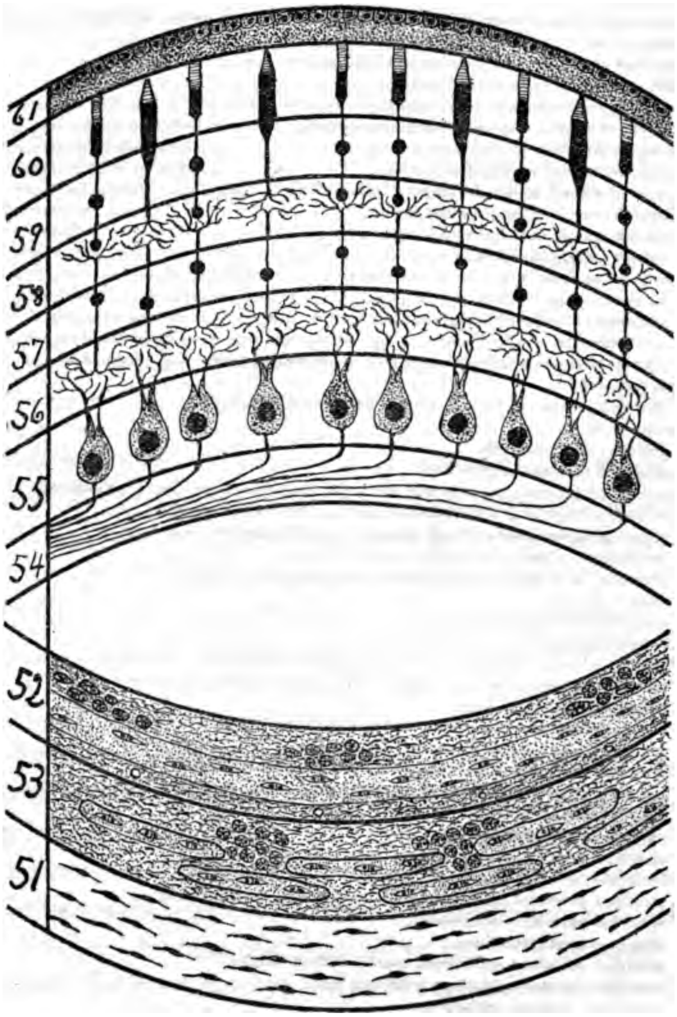


PLATE XIX.

CONNECTIVE TISSUE AND NEURO-EPITHELIAL STRUCTURES FOR THE CONSTRUCTION OF CERTAIN SPECIAL ORGANS.

MODELS NUMBERED AND DESCRIBED.

1. Connective tissue.
2. Connective tissue enclosing sweat glands, tactile corpuscles, blood vessels, nerves and lymphatics.
3. Layer of striped voluntary muscle in transverse section.
4. Layer of striped voluntary muscle in longitudinal section.
5. Layer of smooth muscle in transverse section.
6. Thick layer of smooth muscle in longitudinal section.
7. Very thin layer of smooth muscle in transverse section.
8. Layer of smooth muscle in longitudinal section.
9. Layer of smooth muscle in transverse section.
10. Vascular layer of smooth muscle in longitudinal section.
11. Layer of smooth muscle in longitudinal section.
12. Layer of smooth muscle in longitudinal section.
13. Layer of smooth muscle in oblique section.
14. Layer of connective tissue with blood vessels, nerves and lymphatics.
15. Layer of connective tissue with secreting glands, blood vessels, nerves and lymphatics.
16. Layer of connective tissue with glands of Brunner, blood vessels, nerves and lymphatics.
17. Layer of connective tissue with Peyer's patches, blood vessels, nerves and lymphatics.
18. Layer of connective tissue with solitary glands, blood vessels, nerves and lymphatics.
19. Basement membrane.
20. Layer of connective tissue with blood vessels, nerves and lymphatics.
21. Homogeneous layer.
22. Layer of granular epithelial cells.
23. Layer of stratified pavement epithelium.
24. Layer of compound tubular glands with short necks, long bodies, chief and parietal cells.
25. Layer of compound tubular glands with long necks, short bodies and chief cells.
26. Layer of crypts of Lieberkühn and villi resting upon a connective tissue base.
27. Layer of incomplete crypts embedded in lymphoid tissue.
28. Layer of crypts of Lieberkühn resting upon a connective tissue base.
29. Layer of erectile tissue.
30. Layer of simple cubical epithelium.
31. Layers of stratified, transitional epithelium.
32. Layer of simple, ciliated epithelium in tubular glands resting upon a connective tissue cellular base.
33. Layer of simple, ciliated epithelium in folds resting upon a connective tissue base.
34. Layer of simple, cubical epithelium.
35. Layer of elastic tissue, connective tissue and endothelium.
36. Layer of stratified, ciliated epithelium.
37. Layer of stratified pavement epithelium with undulating lower border.
38. Layer of two rows of pavement epithelium—outer mostly non-nucleated—inner nucleated.
39. Layer of simple columnar epithelium.
40. Layer of endothelium (not in section).
41. Layer of sustentacular cells, sperm cells and spermatozoa.
42. Germ cell enclosed in embryonic epithelial cells.
43. Layer of stratified pavement epithelium with border cells of columnar type.
44. Layer of stratified pavement epithelium.
45. Layer of simple cubical epithelium.
46. Layer of stratified pavement epithelium, mostly without nuclei.
47. Layer of stratified, ciliated epithelium with long cilia.
48. Layer of stratified columnar epithelium.
49. Layer of rodded epithelium.
50. Layer of polygonal epithelium.
51. Layer of a modified form of connective tissue.
52. Layer of connective tissue enclosing C-shaped rings of hyaline cartilage and secreting glands.
53. Layer of connective tissue enclosing plates of hyaline cartilage and secreting glands.
54. Layer of nerve fibers.
55. Layer of nerve cells.
56. Inner molecular layer.
57. Inner nuclear layer.
58. Outer molecular layer.
59. Outer nuclear layer.

MODELS NUMBERED AND DESCRIBED.—*Continued.*

60. Layer of rods and cones.
61. Layer of pigment cells.
62. Layer of simple pseudo-stratified ciliated epithelium.
63. Layer of hair cells and sustentacular cells.
64. Layer of hair cells, pillar cells and sustentacular cells.
65. Layer of olfactory cells and sustentacular cells.
66. Layer of simple pseudo-stratified columnar epithelium.
67. Layer of simple ciliated epithelium.
68. Layer of simple cubical epithelium.
69. Layer of stratified columnar epithelium.
70. Layer of connective tissue.
71. Layer of connective tissue with pigment cells and many blood vessels.
72. Layer of nerve fibers, nerve cells, ganglion cells, rods and cones and pigment cells.
73. Thin layer of connective tissue.
75. Layer of simple cubical epithelium.
76. Thin layer of smooth muscle in outer cross and inner longitudinal sections.
77. Layers of connective tissue and endothelium.
78. Layer of connective tissue upon which are blood capillaries embedded in the under surfaces of respiratory epithelium.

Some confusion may arise in the usual distinction between a coat and a layer. As a matter of fact exact lines of distinction between the two are not drawn. A coat may be a layer or a layer may be a coat. In general a coat is composed of layers and hence is thicker than a layer. However, both terms are merely convenient terms to call attention to a general fact concerning tissue thicknesses or masses and not to a fixed number of cells or fibers or a definite thickness or a mass of tissue, which is always capable of measurement.

Arrangement of Tubes in Five Classes.—The different tubes vary in structure to a considerable extent; but if we examine them all and classify them on the basis of structural agreement we will find that nearly all of them, however widely apart they may appear to be, can be arranged under five classes which will be found to differ from each other by the presence or absence of some distinguishing part. The same functional requirements call for the same type of tube formation, so that if we know where a tube is and what it does we can build the type of tube which belongs to that location. A general tissue formula of construction is employed in order that tube types and not tube specialties may be made.

The five classes of tubes, constructed on a general formula, and examples of them beginning with one layer and increasing to four coats may be arranged as follows:

Type of Tube.	Formation of Tube.	Example.
1. One-layer tube.	Epithelium or endothelium.	Capillary.
2. One-coated tube.	1. Epithelium. Structureless basement membrane.	Acini of any secreting gland.
3. Two-coated tube.	2. Epithelium. Structureless basement membrane. 1. Connective tissue enclosing C-shaped rings of hyaline cartilage and secreting glands.	Trachea.
4. Three-coated tube.	3. Epithelium. Connective tissue base. 2. Muscle—one, two or three layers. 1. Connective tissue.	Epididymis.
5. Four-coated tube.	4. Epithelium. Connective tissue base. Muscle—one or two layers—muscularis mucosæ. 3. Areolar tissue with blood vessels, nerves and lymphatics with or without secreting glands. 2. Muscle—two or three layers. 1. Connective tissue.	Pyloric stomach.

Outlines.—The tubes of the body are constructed in outlines which are printed upon the two inside cardboard leaves of the model case. They are divided into five classes and into non-motor and motor tubes. In the construction of all tubes a general tissue formula is employed as a matter of convenience. Each class of tube and each tube is constructed by building from the outside toward the center. The outlines exhibit the design according to which each tube is constructed. The words in italics call attention to those structures which characterize the organ. The numbers at the right are model numbers. It is thought that a design will create an incentive to build and induce one to demonstrate his personal conclusions concerning mechanical formations. An illustration of the outlines in their application to tubular structures may be seen in Plate XX which follows.

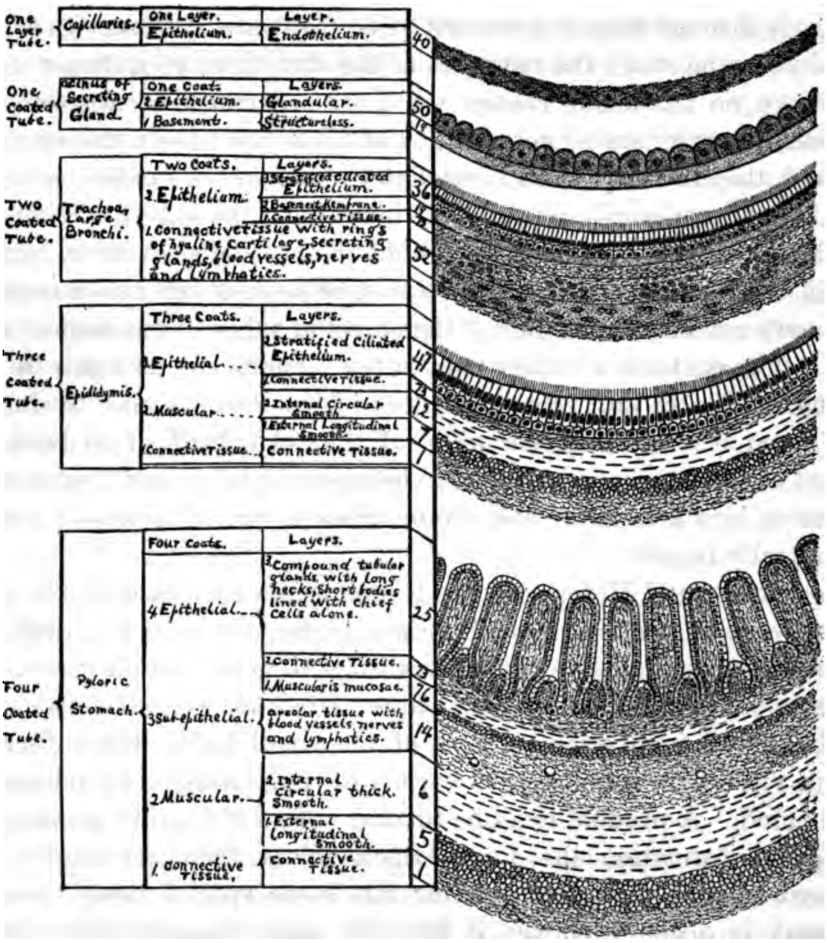


PLATE XX.

OUTLINES APPLIED TO THE STRUCTURAL FORMATION OF THE FIVE TUBE CLASSES.

epithelium is osmotic, such as the alveoli of the lung and the vascular system. This leaves only a few places where it does occur, such as the larynx, trachea, bronchi, nasal ducts, uterus, Fallopian tubes, epididymis, Eustachian tubes and first part of the vas deferens. It is found in these tubes because their motor character requires it. The great majority of the visceral tubes of the body are, therefore, lined by epithelium whose functions are secretory, excretory, absorptive, non-absorptive and protective, and this epithelium is polygonal, polyhedral, columnar, transitional and pavement. Secretory and excretory epithelium is polygonal, polyhedral and columnar; absorptive is columnar and endothelial; non-absorptive is transitional, and protective is pavement. This also facilitates tube construction as their non-motor and motor character enables one to decide what variety of epithelium is present. The classification of the tubes of the body according to their non-motor and motor capacities is given in the outline which follows.

OUTLINE OF NON-MOTOR AND MOTOR TUBES.

	Kind of Tube.	Motor Apparatus.	Class of Tube.	Organs.	Contents.
Tubes.	1. Non-motor.	None.	One layer.	Capillaries.	Liquid.
		None.	One-coated. Plate XXII.	Tubuli seminiferi. Tubuli uriniferi. Crypts of Lieberkühn. Gastric glands. Serous membranes. Graafian follicles. Small ducts. Skin. Hair follicle. Vestibule—utriculus—sacculus. Semi-circular canals. Cochlea. Nasal mucosa (olfactory part). Acini of secreting glands. Lacrimal sac.	Small liquid.
	2. Motor.	Muscular.	Three-coated. Plate XXXIII.	Vagina. Upper ureters, pelvis of kidney. Lower ureters. Urinary bladder. Gall bladder. Small artery. Small vein. Large ducts. Seminal vesicles. Urethra. Vas deferens (second part).	Large solid and small liquid.
			Four-coated. Plate XXXVI.	Upper œsophagus. Lower œsophagus. Cardiac stomach. Pyloric stomach. Duodenum. Jejunum, Ileum. Large Intestine. Vermiform appendix.	Large liquid and solid.
		Ciliary.	Two-coated. Plate XXVIII.	Trachea. Large bronchi.	Small liquid and large gaseous.
			One-coated. Plate XXIII.	Tympanum of ear. Eustachian tube. Nasal mucosa (respiratory part). Nasal duct.	Small liquid.
		Muscular ciliary.	Three-coated. Plate XXXIV.	Fallopian tube. Uterus. Epididymis. Medium bronchi. Small bronchi. Vas deferens (first part).	Large solid and small liquid.

CONSTRUCTION OF TUBULAR ORGANS BY MODELS. NUMBERS ARE MODEL NUMBERS.

ORGANS.	ONE-LAYER TUBE.	ONE-COATED TUBE.	ONE-COATED TUBE.	TWO-COATED TUBE.	THREE-COATED TUBE.	THREE-COATED TUBE.	FOUR-COATED TUBE.
	NON-MOTOR. No.	NON-MOTOR. Nos.	CILIARY-MOTOR. Nos.	CILIARY-MOTOR. Nos.	MUSCULAR-MOTOR. Nos.	MUSCULAR CILIARY-MOTOR. Nos.	MUSCULAR-MOTOR. Nos.
Capillaries	40						
Tubuli seminiferi		19.41					
Secreting glands: Thyroid		19.34					
Parotid		19.50					
Submaxillary and sublingual		19.50					
Sub-epithelial		19.50					
Glands of stomach		19.39					
Crypts of Lieberkühn		19 30					
Liver		50					
Pancreas		19.45					
Sweat glands		19.75					
Sebaceous glands		19.50					
Mammary glands		19.30					
Meibomian glands		19.50					
Lachrymal glands		19.50					
Prostate gland		19.50					
Cowper's glands		19.50					
Nabothian glands		19 50					
Bartholin's glands		19.50					
Glands of Littré		19 30					
Tubuli uriniferi: Neck		19.68					
Proximal convolution		19.49					
Descending spiral		19.49					
Descending straight		19.30					
Henle's loop		19.30					
Ascending spiral		19.34					
Irregular portion		19.75					
Distal convolution		19.49					
Junctional portion		19.30					
Duct of Bellini		19.39					
Alveoli of lung		78					
Graafian follicle		73.42					
Small ducts[1]		19.39					
Hair follicle		1.19.43.38					
Skin		2.37.22.21.46					
Vestibule-utriculus and sacculus		1.34 & 1.63					
Semicircular canals		1.68 & 1.63					
Cochlea		1.64					
Lacrimal sac		15.66					
Nasal olfactory mucosa		1.65					
Nasal duct, upper		15.23					
Serous membranes		1.77					
Tympanum of ear			15.62				
Eustachian tube			1.62 & 1.36				
Nasal duct, lower			15.36				
Nasal respiratory mucosa			1.36				
Trachea and large bronchi				52.73.19.36			
Vas deferens (2d part)					1.5.8.9.73.69		
Upper ureter					1.8.9.73.31		
Lower ureter					1 5.8.9.73.31		
Urinary bladder					1.5.8.9.73.31		
Vagina					1.9.12.20.23		
Artery-vein					1.11.35		
Large lymphatic					1.12.77		
Gall bladder					1.7.12.73.19.39		
Large duct					1.7.12.73.19.39		
Seminal vesicles					1.9.12.73.66		
Corpus spongiosum					1.29.73.69 & 31		
Medium bronchus						53.8.73.19.36	
Small bronchus						1.8.73.19.67	
Vasa efferentia of the testicle						1.7.12.73.36 & 69	
Epididymis						1.7.12.73.47	
Vas deferens (1st part)						1.5.8.9.73.36	
Fallopian tube						1.9.12.20.33	
Uterus						1.5.10.9.20.32	

CONSTRUCTION OF TUBULAR ORGANS.—*Continued.*

ORGANS.	ONE-LAYER TUBE.	ONE-COATED TUBE.	ONE-COATED TUBE.	TWO-COATED TUBE.	THREE-COATED TUBE.	THREE-COATED TUBE.	FOUR-COATED TUBE.
	NON-MOTOR. No.	NON-MOTOR. Nos.	CILIARY-MOTOR. Nos.	CILIARY-MOTOR. Nos.	MUSCULAR-MOTOR. Nos.	MUSCULAR CILIARY-MOTOR. Nos.	MUSCULAR-MOTOR. Nos.
Upper œsophagus							1.3.4.15.76.73.23
Lower œsophagus							1.9.8.15.76.73.23
Cardiac stomach							1.9.8.13.14.76.73.24
Pyloric stomach							1.5.6.14.76.73.25
Duodenum							1.9.8.16.76.73.26
Jejunum ileum							1.9.8.17.76.73.26
Large intestine							1.9.8.18.76.73.28
Vermiform appendix							1.9.8.20.7.27

EYE—ADAPTATION OF THE TUBE.

ORGANS.		ONE COAT. NON-MOTOR.
Retina		54.55.56.57 58.59.60.61
Cornea		44.19.51.21.30
Coats of eye-ball		70.71.72

We may consider the non-motor tubes first, as these are the simplest in structure and naturally become fundamental in more complex formations. The one layer and most of the one coated tubes belong to this class.

One Layer Tubes, Non-Motor (see Plate XXI).—The one layer tube is composed of one single layer of pavement epithelial or endothelial cells united at their edges by cement. To this class of tube belong only the blood and lymph capillaries. On account of the single layer of cells forming their walls, they must necessarily be incapable of great strength and are therefore very short. They are also but little greater in diameter than the blood or lymph cells which pass through them. The blood capillaries form those parts of the vascular system intermediate between the arteries and veins, and here it is that the processes, by which nutrition is maintained, are carried on.

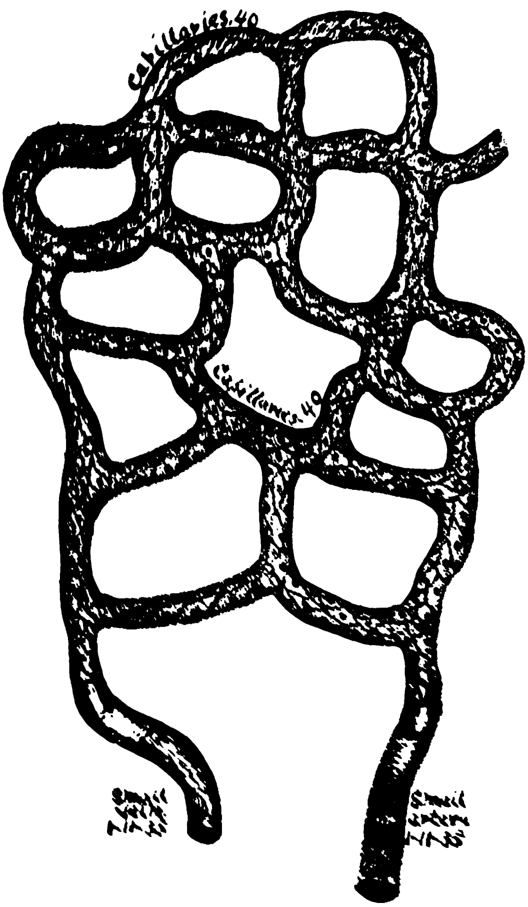


PLATE XXI.

A Small Portion of the Circulatory System: a Small Artery, Capillary Plexus and Small Vein. (Numbers on all plates are model numbers.

The single layer character of the walls of these tubes adapts them to the osmotic or secretory conditions, as the laws of osmosis and secretion require very thin animal structures between interchanging liquids. Whatever passes out of the blood or into it must pass through this extremely short portion of the thinnest part of the circulatory system. Anything more than a single layer of pavement cells in the structure of these tubes would defeat the whole process of nutrition and elimination. Since it is the simplest variety of tissue which is found in the body and

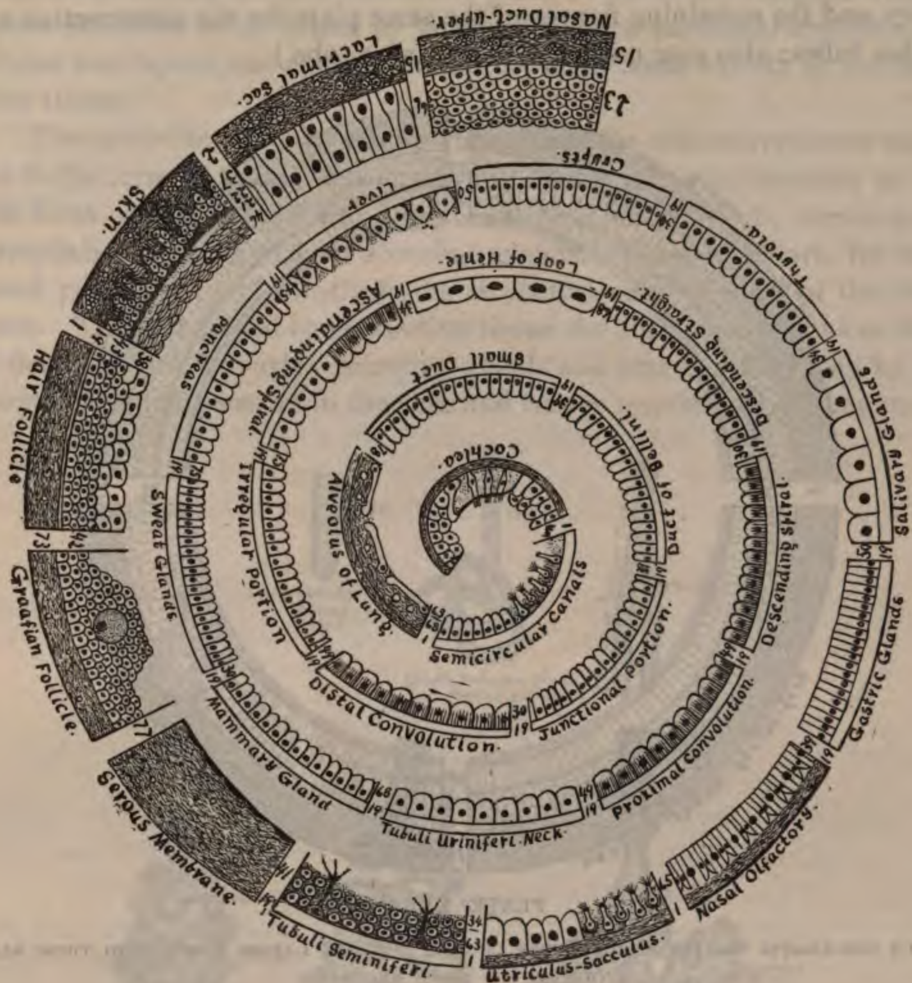


PLATE XXII.

THIRTY-ONE ONE-COATED, NON-MOTOR TUBES IN ONE DIAGRAM, SHOWING LAYERS COMMON TO THEM ALL. (Numbers are model numbers.)

has a definite function, it may be taken as a fundamental type of tube formation. It does not follow from this that the same *kind* of epithelium must form the lining of all tubes; but that *some* form of epithelium must be found there. To this may be added other tissues for protection, support, vascular supply, motion and form, and the remaining four classes of tubes may be constructed. (See Plate XX, fig. 40, for the capillary, and the remaining figures of the same plate for the construction of other tubes; also case outline of a one layer tube.)

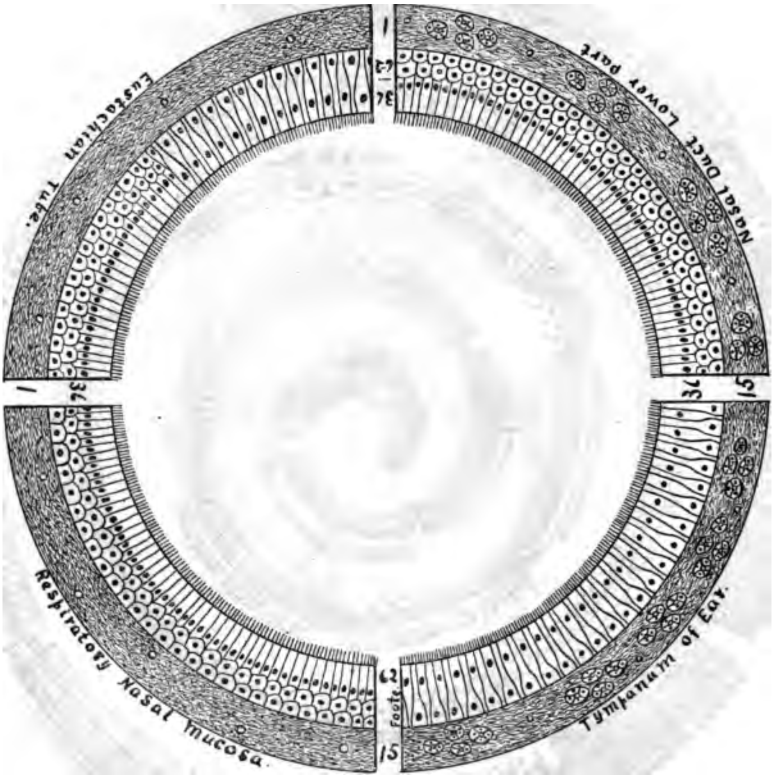
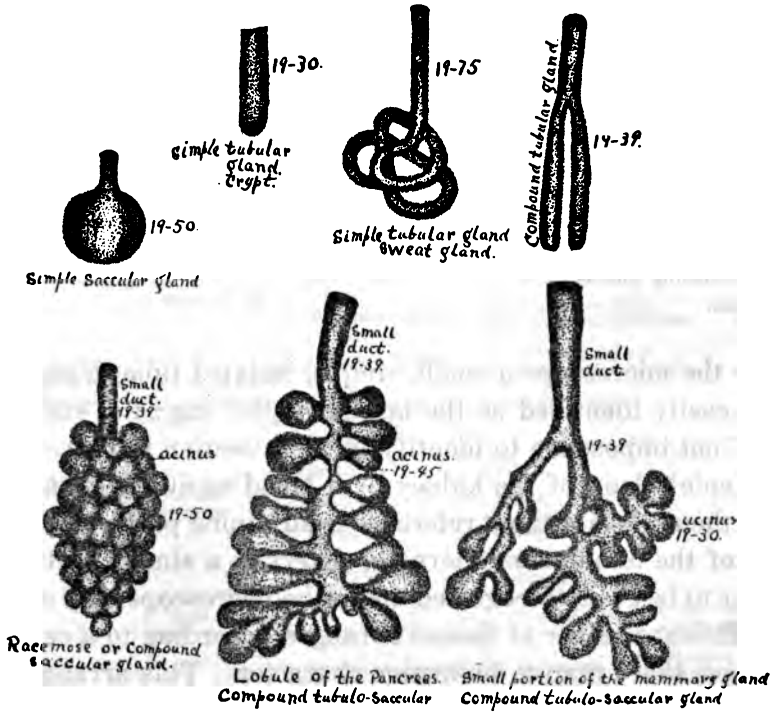


PLATE XXIII.

FOUR ONE-COATED CILIARY MOTOR TUBES IN ONE, SHOWING LAYERS COMMON TO THEM ALL.
(Numbers are model numbers.)

One Coated Tubes (Non-Motor and Ciliary Motor) (see Plates XXII, non-motor; XXIII, ciliary motor—mic. and XXIV, XXV, XXVI—mac.). —The next form or class of tube, somewhat more complex in formation and function than the one layer tube, is the one coated tube. It may be formed from a one layer tube by adding directly to its outer aspect some other varieties of tissue. In the construction of this tube from a one layer tube a general tissue formula is employed and not a special or restrictive one; that is, the one layer tube is understood to be not an osmotic or absorptive tube restrictively but a tube of any function which gives character to the organ by virtue of its own particular epithelium. It has two layers, one epithelium and the other some variety of connective tissue.

The epithelium may be of any variety and the connective tissue may be in the form of a basement membrane, structureless in character or in the form of areolar tissue or base, containing blood vessels, nerves and lymphatics, with or without secreting glands. These tubes are, for the most part, small and constitute the structural units of most of the viscera. They are joined by connective tissue and form such organs as the kidneys, testicles, ovaries, secreting glands and lungs, or they may be in large expanded areas as in the skin and serous membranes or they may



One coated tubes. non-motor. secreting glands-acini

PLATE XXIV.

TYPES OF SECRETING GLANDS.

be in the form of a prolonged tube enclosed in a bony canal as in the internal ear. At first thought it may seem somewhat confusing to associate as belonging to the same class of tube such structures as the acini of secreting glands, internal ear and skin; but if we consider them from the viewpoint of their functional operations, we shall see that the first are secreting organs, while the last two are sensory. The structural requirements of these two classes of organs are essentially the same; that is, the functionating part must be as near to the blood current as possible. This type of tube, therefore, is adapted by structure to functions of secretion and special sense. Secreting glands are all constructed on the same plan, viz: a basement membrane with a circulation on one side of it and some variety of epithelium on the other. This arrangement brings the functional epithelium as near to the blood stream as it is possible to get it. It is as essential that neuro-epithelium should be close to the blood stream as it is that secreting epithelium should be, for all highly organized cells require such positions. To this class of tube belong chiefly the secreting organs and the organs of special sense, as:

Secretory:

Tubuli uriniferi of the kidneys,
Tubuli seminiferi of the testicles,
Graafian follicles of the ovaries,
Alveoli of the lungs,
Acini of secreting glands,
Small ducts.

Sensory:

Vestibules, utriculi, sacculi, semicircular canals and cochleæ of the ears; skin, hair follicles and serous membranes.

Under the microscope a small, simple, isolated tube in cross section is not as easily identified as the large complex one; for example, it is difficult if not impossible to identify in cross section the ascending portion of Henle's loop of the kidney or a blood capillary if they are observed by themselves without reference to adjoining parts, while the identification of the œsophagus, uterus or artery is a simple matter. That is, in order to be easily recognized under the microscope, any organ must have a sufficient number of tissues arranged according to a certain fixed plan, to give that organ a distinctive character. This arrangement has more to do with the act of recognition than a single cell or any single part. We seldom see one kidney tube or secreting gland acinus in cross section, but many of them united by connective tissue, so that when one

SENSORY SYSTEM.

ORGAN.	DIVISIONS.	SUBDIVISIONS.	FURTHER DIVISIONS.	STRUCTURE.		
3. Ear.	1. External ear.	1. Pinna.	1. Skin.	Like the structure of skin elsewhere.		
			2. Glands.	Sebaceous in character.		
			3. Connective tissue.	Like any subcutaneous tissue.		
		2. External auditory canal.	1. Skin.	Same as elsewhere.		
			2. Cartilaginous part.	Yellow elastic.		
			3. Glands.	Sebaceous, ceruminous.		
			4. Bony part.			
		3. Membrana tympani.	1. Lamina propria.	1. Outer layer.	Connective tissue fibers radiating from the periphery of the tympanum to the attachment of the head of the malleus.	
				2. Inner layer.	Connective tissue fibers running circularly.	
			2. Cutaneous layer.	Like skin elsewhere except that it is thinner.		
			3. Mucous layer.	1. Tunica propria.	2.	1. White fibrous tissue. 2. Yellow elastic tissue.
				2. Epithelium.	1.	Polyhedral cells.
	2. Middle ear or tympanum.	1. Wall of the tympanic cavity.	1. Bone and periosteum.			
			2. Mucous membrane.	1. Tunica propria.	A tissue resembling lymphoid.	
				2. Epithelium.	Polyhedral cells over the ossicles, simple pseudostratified ciliated elsewhere.	
				3. Glands.	Tubular.	
		2. Mastoid cells.	1. Bone and periosteum.			
			2. Mucous membrane.	1. Connective tissue. 2. Polyhedral epithelium.		
		3. Secondary tympanic membrane.	1. Mucous membrane.	1. Connective tissue. 2. Polyhedral epithelium.		
			2. Lamina propria.	Connective tissue.		
			3. Endothelium.			
		4. Ossicles or ear bones.	1. Incus.	Anvil.		
			2. Malleus.	Mallet.		
			3. Stapes.	Stirrup.		
		5. Eustachian tube.	1. Framework.	1. Bone. 2. Cartilage.		
			2. Mucous membrane.	1. Tympanic.	1. Connective tissue. 2. Ciliated epithelium.	
				2. Laryngeal.	1. Connective tissue. 2. Columnar epithelium.	
				3. Bony part.	1. Connective tissue. 2. Cubical epithelium.	

SENSORY SYSTEM.—*Continued.*

Organ.	Divisions.	Description.	Divisions.	Subdivisions and Structure.				
Internal ear.			1. Cochlea.	1. A tapering bone tube wound spirally around an axis or modiolus.				
				2. Ductus cochlearis or scala media.	Central, small, triangular canal attached by base to the outer wall of bone tube and by the opposite border to the spiral lamina.	1. Tunic of white fibrous tissue. 2. Pavement epithelium. 3. Cubical epithelium partly.		
				3. Scala vestibuli.	Superior division of perilymphatic space.	1. Periosteum as a base. 2. Endothelium.		
	1. Bony labyrinth.	Outside bony wall of the whole internal ear.		4. Scala tympani.	Inferior division of perilymphatic space.	1. Periosteum as a base. 2. Endothelium.		
				5. Membrane of Reissner.	One side of ductus cochlearis.	1. Endothelium. 2. Connective tissue base. 3. Polyhedral epithelium.		
				6. Basilar membrane.	The other side of the ductus cochlearis.	1. Cells of Deiter. 2. Cells of Hensen. 3. Cells of Claudius.		
				7. Crista basilaris.	Ridge to which basilar membrane is attached.	Thickened periosteum.		
				8. Stria vascularis.	A richly vascular structure.	Epithelium on both sides of blood vessels.		
				9. Ductus cochlearis.	1. Limbus.	1. Thick periosteum.		
					2. Basilar membrane.	2. Neuro-epithelium.		
				10. Organ of Corti.	1. Zona tecta or inner zone. 2. Zona pectinati or outer zone.	1. Epithelial arches.	Long cells joined like rafters.	Neuro-epithelium.
	2. Perilymphatic space.	Space between bony labyrinth and membranous labyrinth filled with liquid.				2. Tunnels of Corti.	Space beneath the rafters.	Filled with semi-fluid.
						3. Pillars.	1. Inner—short.	5,600 in number.
							2. Outer—long.	3,850 in number.
				11. Hair cells within the arches of Corti.	1. Inner.	Columnar bodies with oval nuclei and granular protoplasm from the outer ends of which project 20 hairs.		
					2. Outer.	Three or four rows of columnar cells, with expanded, rounded ends from which project 20 hairs.		
				12. Cells of Deiter.	1. Epithelium ending in end plates and resting upon basilar membrane. 2. Long, columnar cells with spherical nuclei and pyramidal ending.			
			2. Vestibule.	1. Anterior saccule.	1. White fibrous tissue.			
					2. Polyhedral epithelium except over the maculæ cribosæ and acusticæ.			
	3. Trabeculæ.	Prolongations from the periosteum of the outer bony wall extending between that wall and the central membranous tube.			3. Macula cribosa. 4. Macula acustica.	Regions receiving ends of auditory nerve.		
					5. Sustentacular cells—pigmented.			
					6. Hair cells.	Columnar, pigmented cells with spherical nuclei and a single hair projecting from the free ends.		
				2. Ductus endolymphaticus.	A duct between the saccule and utricle.			
				3. Posterior utricle.	Larger than the saccule—same in structure. Has the five openings of three semicircular canals.			
				4. Otolith membrane.	Membrane of otoliths, ear stones or crystalline bodies embedded in a soft gelatinous substance covering the free surface of the neuro-epithelium of the saccule and utricle.			

SENSORY SYSTEM.—*Continued.*

ORGAN.	DIVISIONS.	DESCRIPTION.	DIVISIONS.	SUBDIVISIONS AND STRUCTURE.					
Internal ear.	4. Membranous labyrinth.	Central membranous tube of the whole internal ear.	3. Semicircular canals.	1. External. 2. Superior. 3. Posterior.	Begin and end in the utricle.	1. White fibrous tissue base. 2. Polyhedral epithelium.			
						3. Ampulla.	Dilated parts near the entrances to the utricle.	Crista acustica.	Area of neuro-epithelium as a perceptive apparatus like other similar parts in structure.
			4. Auditory nerve.	1. Vestibular.					
				2. Cochlear.	1. Branches communicating laterally with the spiral canal of bony lamina. 2. Radiating bundles extending to the neuro-epithelium.				

of the one coated tubes is built up with the models it does not seem to resemble the pictures of the text books or of the microscope. It is only necessary, however, to isolate one tube of the microscopic picture for comparative study. In fig. 40, of Plates XVII and XX, the blood capillary is represented longitudinally and not in cross section for the reason that a simple pavement epithelium or endothelial cell in cross section is not recognizable on account of its extreme thinness. The one layer and one coated tubes, with few exceptions, do not have a motor apparatus because none is required. In the secreting organs they con-

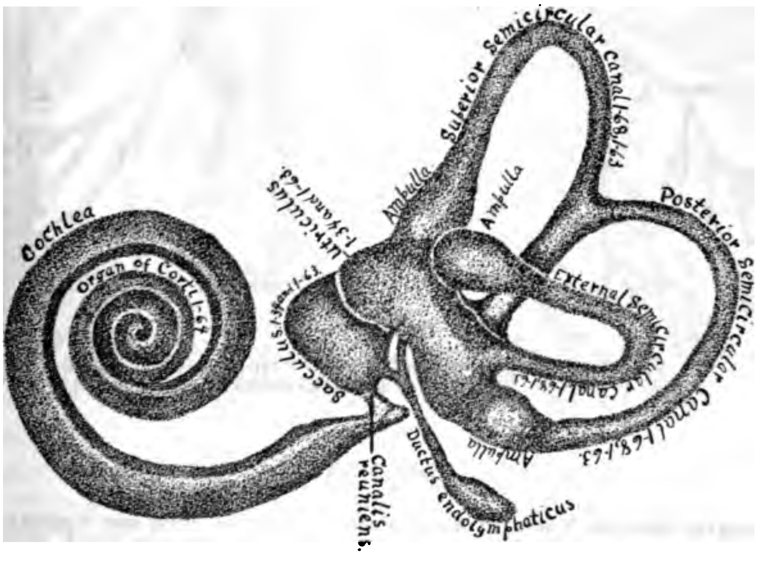


PLATE XXV.

ONE-COATED TUBE. NON-MOTOR. MEMBRANOUS LABYRINTH OF INTERNAL EAR.

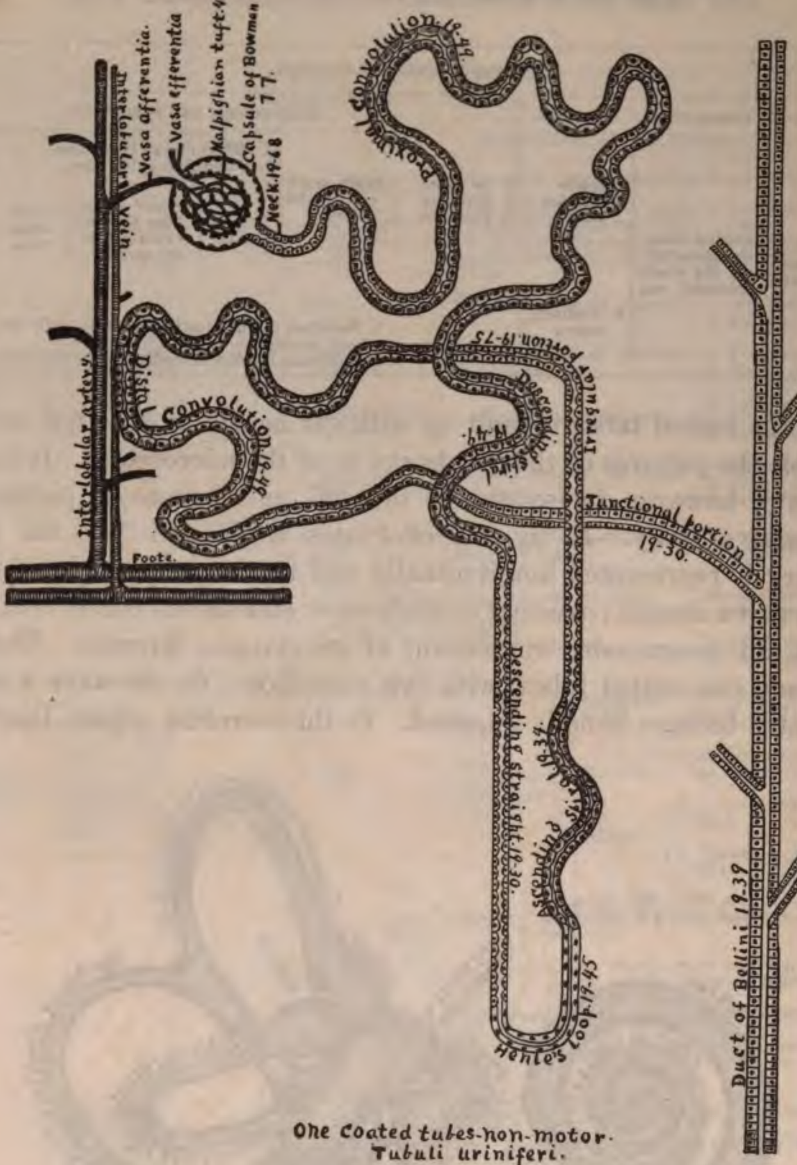


PLATE XXVI.

DIAGRAM SHOWING KIDNEY TUBE AND ITS CONNECTION WITH THE CIRCULATION.
(Numbers are model numbers.)

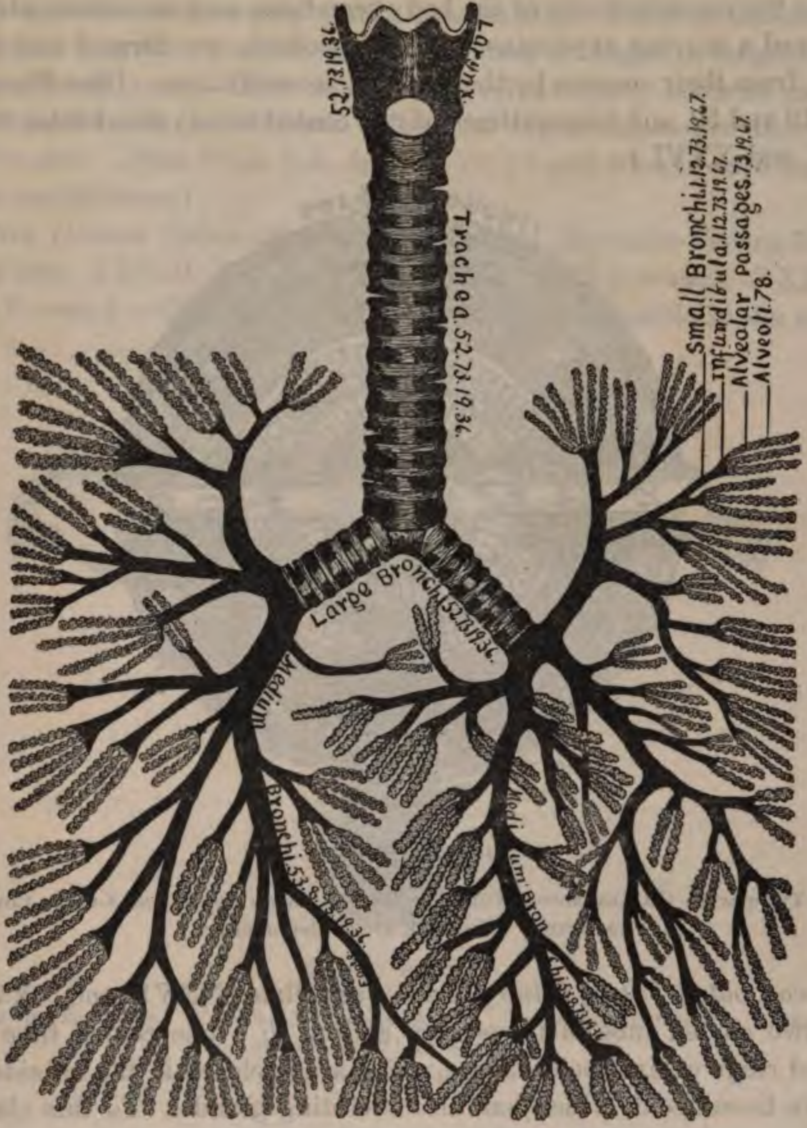

52.73.19.36.
Larynx.
Trachea.52.73.19.36.
Small Bronchi.1.12.73.19.67.
Infundibula.1.12.73.19.67.
Alveolar passages.73.19.67.
Alveoli.78.
Large Bronchi.52.73.19.36.
Medium Bronchi.53.8.13.19.36.
Medium Bronchis.53.73.19.36.

PLATE XXVII.

THREE-COATED TUBES—MEDIUM AND SMALL BRONCHI—MUSCULAR-CILIARY MOTOR. TWO-COATED TUBES LARYNX, TRACHEA, LARGE BRONCHI—CILIARY MOTOR. RESPIRATORY SYSTEM.

stitute the manufactories of the body secretions and excretions which do not need a moving apparatus until the products are formed and forced away from their sources by the force of accumulation. (See Plate XX, figs. 19 and 50, and case outlines of one coated tubes; also Plates XXIV, XXV and XXVI.)

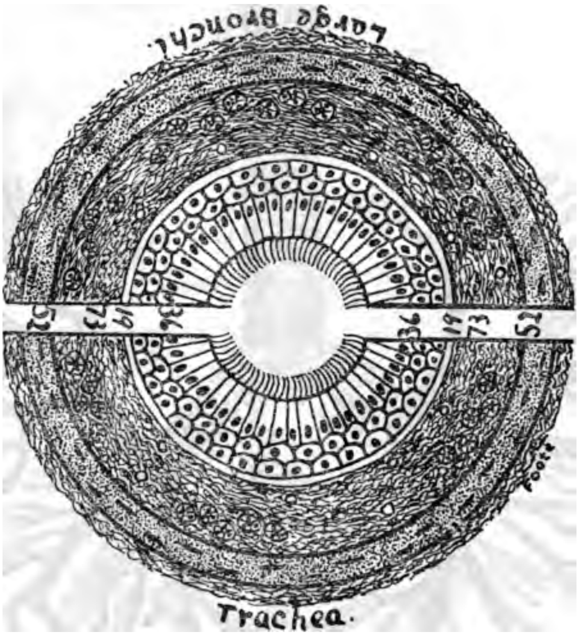


PLATE XXVIII.

TWO TWO-COATED CILIARY MOTOR TUBES IN ONE, SHOWING COATS AND LAYERS COMMON TO BOTH. (Numbers are model numbers.)

Two Coated Tubes, Ciliary-Motor (see Plates XXVII and XXVIII). —A two coated tube is formed by adding to a one coated tube "C" shaped rings of hyaline cartilage which are enclosed in the outside connective tissue coat, which has also secreting glands. To this class of tube belong the trachea and large bronchi.

The characteristic difference between this tube and the one coated tube is in the presence of the cartilage rings (see Plate XXVIII). The essential requirements of this class of tubes are two; that they constantly be kept open and that their very small liquid contents be moved towards the upper end. The first requirement is met by the cartilage rings, the second by cilia. A muscular coat is unnecessary. Between the ends of the rings a very little smooth muscle is found, arranged in longitudinal and transverse layers. This muscle, however, evidently takes no part in the propulsion of the contents. The two coated tubes are therefore ciliary-motor. (See Plate XX, figs. 52, 73, 19 and 36, and case outline of two coated tubes.)

Three Coated Tubes, Muscular-Motor and Muscular-Ciliary-Motor (see Plates XXVII, XXIX, XXX, XXXI, XXXII—mac., XXXIII, XXXIV—mic.).—These tubes are mostly large and visible to the naked eye. They may be formed from a two coated tube by taking out its cartilage rings and adding one, two or three layers of smooth muscle in the form of a coat. The two coated tubes are the only ones the diameters of which must of necessity remain unchanged and hence the only tubes having cartilage rings. They may be looked upon as unique tubes provided with one variety of connective tissue for the special purposes of

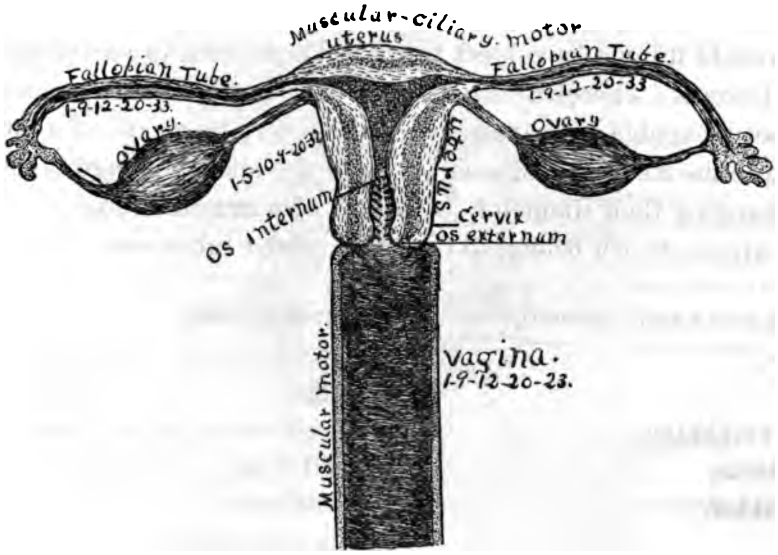


PLATE XXIX.

THREE-COATED TUBES. VAGINA—MUSCULAR MOTOR. FALLOPIAN TUBES AND UTERUS, MUSCULAR-CILIARY MOTOR.
FEMALE GENITAL SYSTEM.

one location and the cartilage rings can be removed without essentially changing the character of tube formation. It is thought best to separate the trachea and large bronchi which are outside the lungs from the medium and small bronchi which are inside the lungs, because structurally and functionally they differ so widely from each other. The trachea and large bronchi are simply open tubes for the free income and outgo of air, their constantly open character being the essential one; while the medium and small bronchi are open tubes kept open by over-lapping cartilage plates, and subject to changes in diameter according to the respiratory requirements. The volume of air in the trachea and large bronchi must always remain about the same, while in the medium and small bronchi it must be subject to control according to variations in the oxygen income. Therefore, the trachea and large bronchi are open cartilage tubes incapable of changing their diameters by means of a muscular coat, while the medium and small bronchi are open cartilage tubes capable of changing their diameters by means of a muscular coat.

The organs which belong to the three coated tubes are:

Medium and small bronchi,
Arteries,
Veins,
Large lymphatics,
Large ducts,
Gall bladder.
Fallopian tubes,
Uterus,
Vagina,
Vasa-efferentia of testicles,
Epididymis,
Vas deferens,
Seminal vesicles,
Ureters,
Urinary bladder,
Urethra.

These tubes are muscular-motor and muscular-ciliary-motor. They are adapted to a progressive or intermittent motion of their contents and hence some have muscle, others cilia and muscle. The muscular coat may have one, two or three layers. The uterus, vas deferens, lower ureters and bladder have three layers. The Fallopian tubes, vagina, epididymis, seminal vesicles, upper ureters and large ducts have two layers. The arteries and veins have one layer.

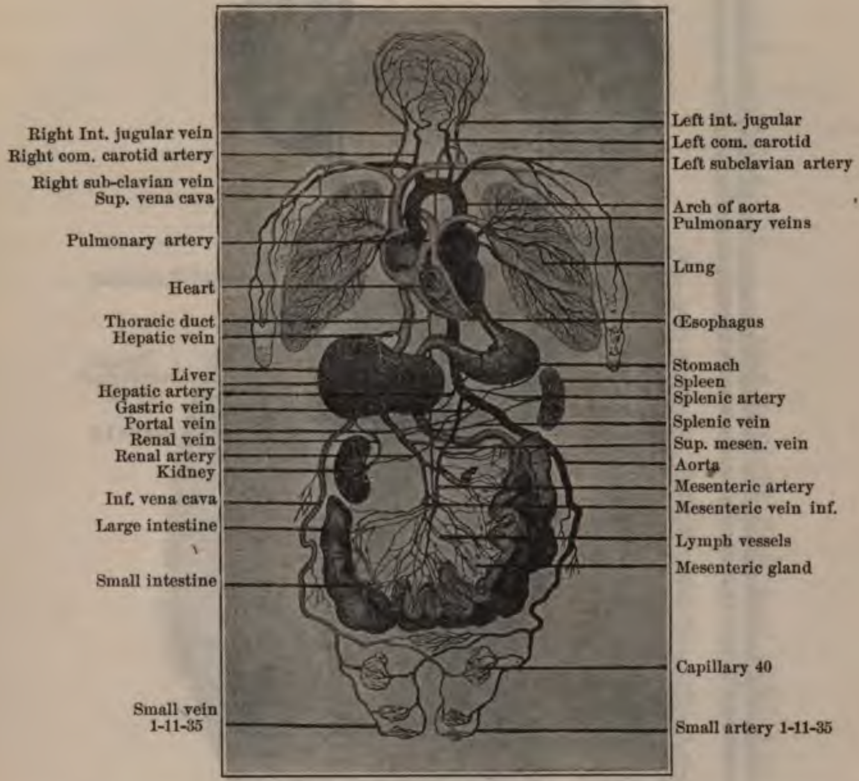


PLATE XXX.

DIAGRAM OF THE CIRCULATION.

Three-coated tubes—Muscular motor. One-layer tubes—Capillaries non-motor. Modified muscular motor tubes—Alternating layers of elastic tissue and smooth muscle—Large blood vessels.

In the bladder a hydrostatic pressure is exerted in all directions and hence it requires a muscular coat acting in all directions.

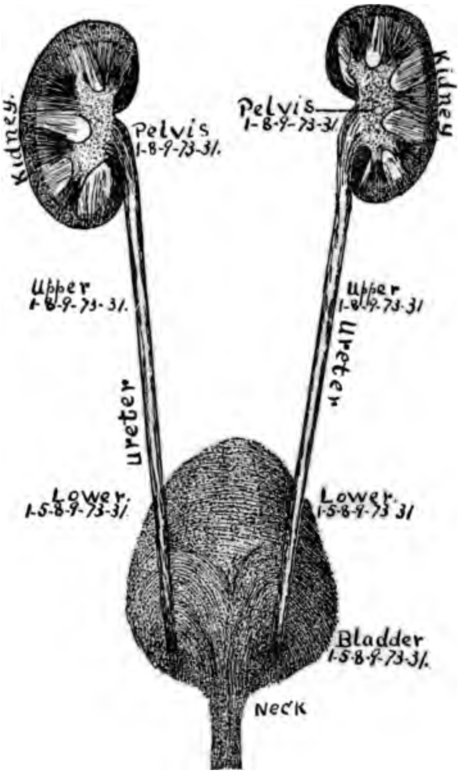


PLATE XXXI.

THREE-COATED TUBES—MUSCULAR-MOTOR. PELVIS OF KIDNEY-URETER-BLADDER.

The larger blood vessels do not have the definite coat, but have smooth muscle and elastic tissue intermixed.

The Fallopian tubes, uterus, epididymis, first part of the vas deferens, medium and small bronchi have both muscle and cilia, hence are provided with two sets of motor apparatus. The presence of a muscular coat in the walls of tubes shows that their contents may be large and continually or intermittently in motion and that considerable force may be required to move them. The presence of cilia in the walls of tubes shows that their contents may be very small and continually in motion

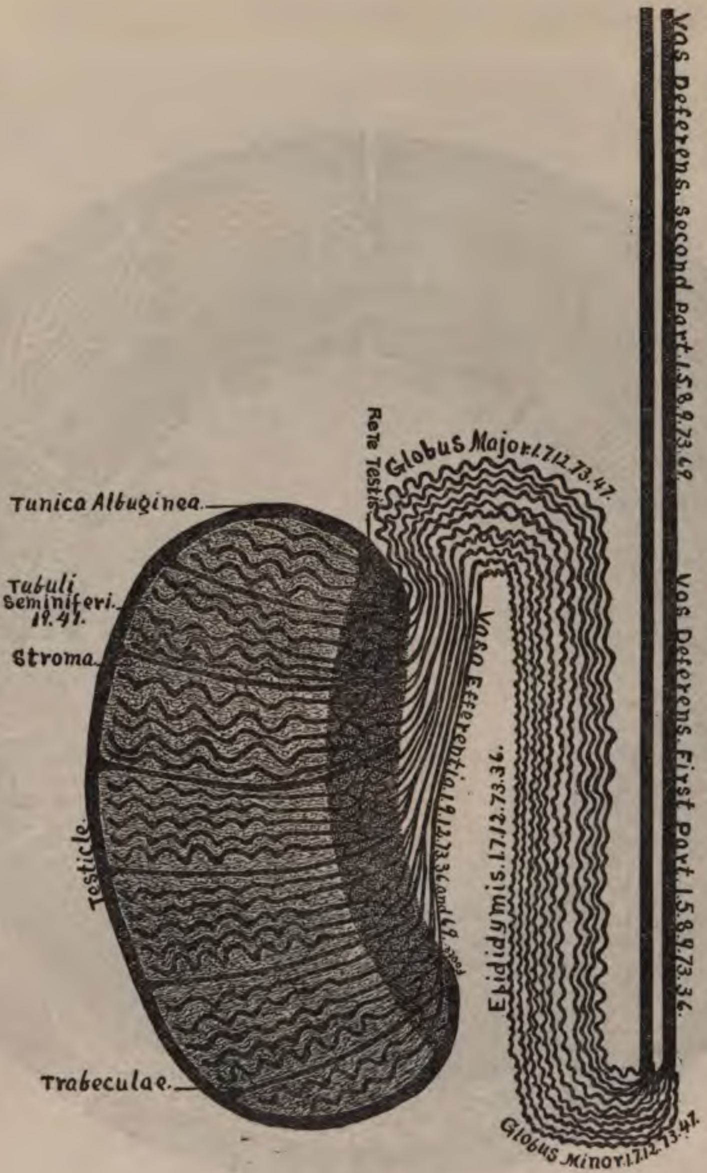

Vas Deferens. Second part.1.5.8.9.73.49.
Rete Testis
Globus Major.1.7.12.73.47.
Tunica Albuginea.
Tubuli Seminiferi. 19.41.
Stroma.
Vasa Efferentia.1.9.12.73.36 and 49.
Epididymis.1.7.12.73.36.
Vas Deferens. First Part.1.5.8.9.73.36.
Testicle.
Trabeculae.
Globus Minor.1.7.12.73.47.

PLATE XXXII.

THREE-COATED TUBES. MUSCULAR-CILIARY-MOTOR.

Epididymis, globus major, globus minor and first part of vas deferens. Muscular-motor, Second part of vas deferens. Vasa efferentia have alternating patches of muscular-ciliary and muscular-motor structures. One-coated tubes—Non-motor, tubuli seminiferi.

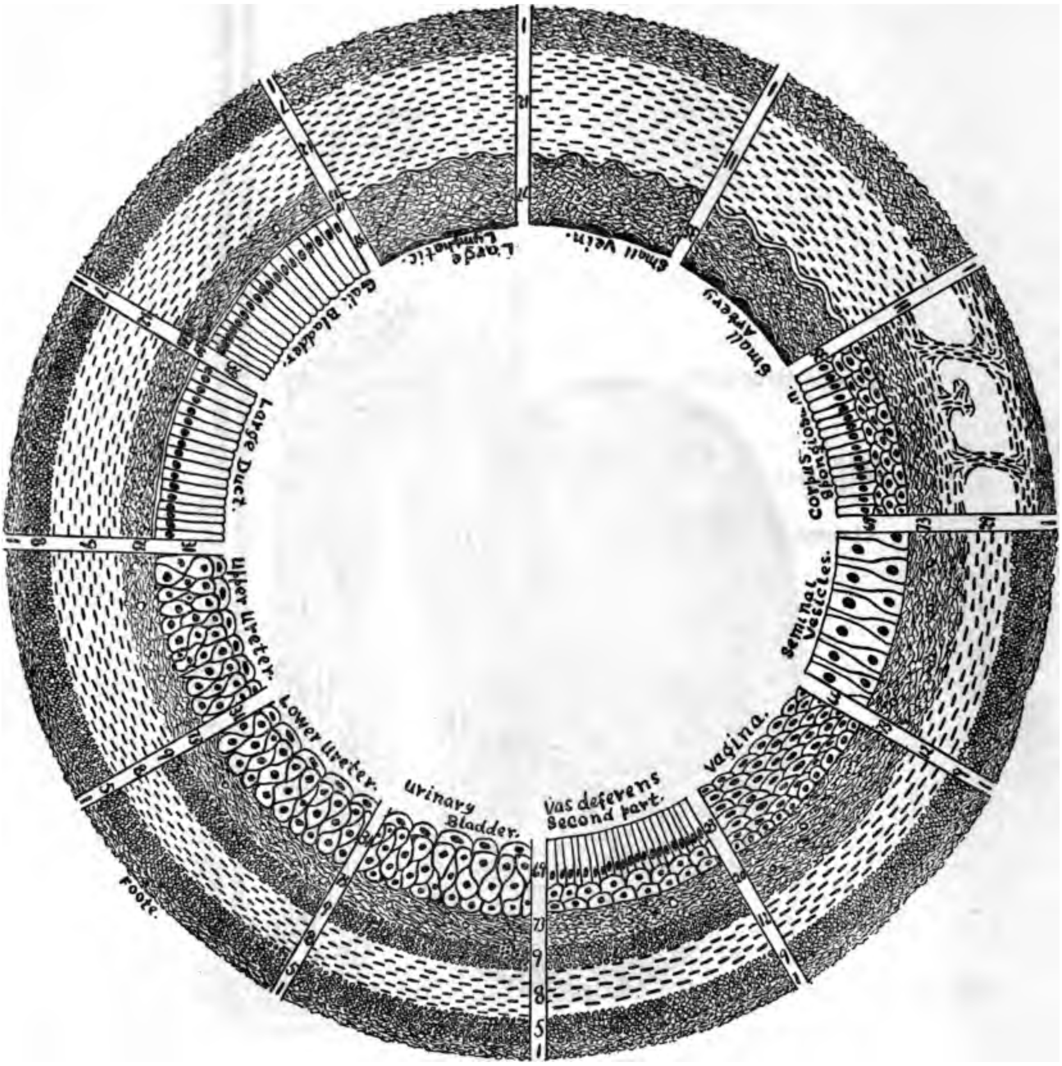


PLATE XXXIII.

Twelve Three-coated Muscular Motor Tubes in one, Showing Coats and Layers Common to them all. (Numbers are model numbers.)

and that very little force is required to move them. The presence of both muscle and cilia shows that the contents may be large and moved with difficulty or small and easily moved. The circulatory tubes differ from other tubes in this respect; that their contents are propelled by a force from behind and hence a distinct muscular coat is unnecessary.

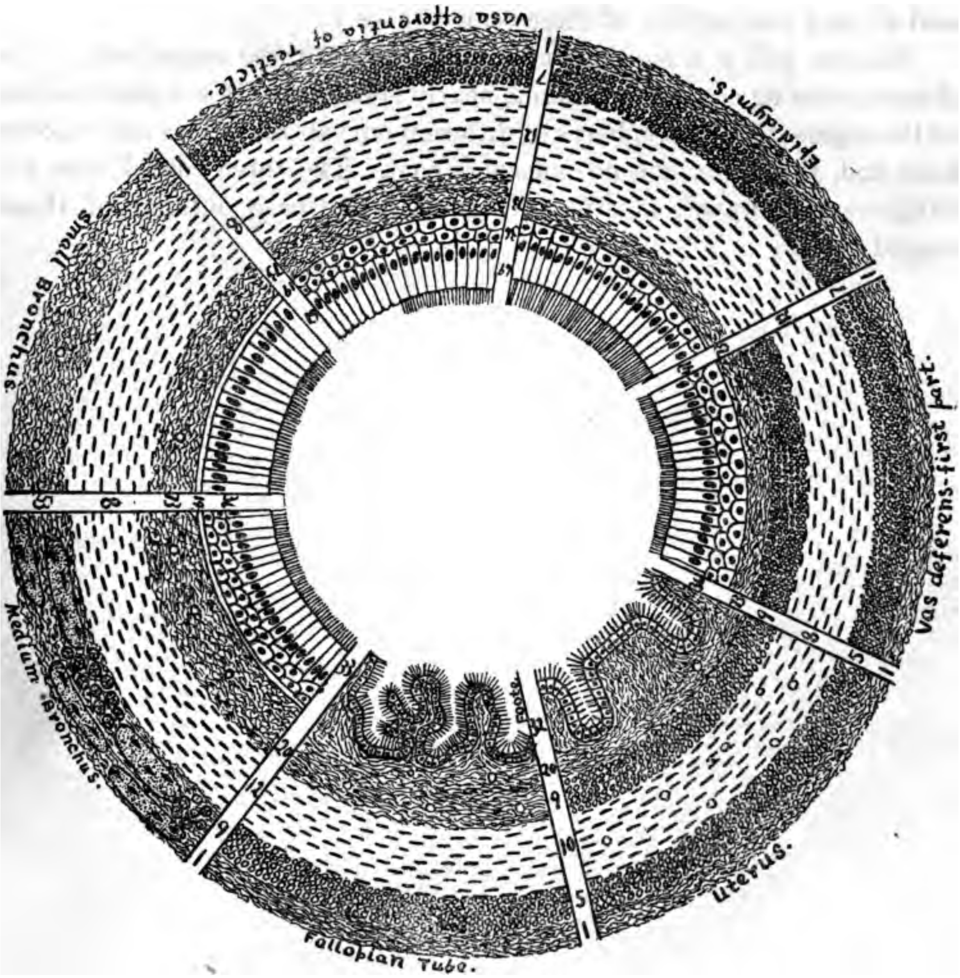


PLATE XXXIV.

Seven Three-coated Muscular Ciliary Motor Tubes in One, Showing Coats and Layers Common to them all. (Numbers are model numbers.)

The epithelium varies in kind according to the location of the tube, nearly all varieties being found. In one instance, the medium bronchi,

SENSORY SYSTEM.—*Continued.*

Organ.	Divisions.	Description.	Subdivisions.	Structure.
2. Eye ball.	1. Cornea.	The anterior transparent one-sixth part of the eye ball.	1. Anterior epithelium.	Stratified pavement epithelium.
			2. Anterior limiting membrane, membrane of Bowman.	A highly developed basement membrane.
			3. Substantia propria.	Parallel lamellæ of interlacing bundles of fibrous tissue united by cement. Branched connective tissue cells and wandering cells.
			4. Posterior limiting membrane, membrane of Descemet.	1. A clear homogeneous basement membrane. 2. Endothelium.
			5. Posterior epithelium.	A single layer of polyhedral epithelial cells.
	2. Sclera.	The posterior opaque five-sixths part of the eye ball.	1. Cells.	1. A single layer of flattened epithelial cells.
			2. Base.	2. Interlacing bundles of fibrous tissue extending meridionally and equatorially.
			3. Cells.	3. Single layer of flattened epithelial cells.
	Lamina fusca.	The rough, brown, inner surface of the sclera.	1. Base.	1. A pigmented connective tissue.
			2. Cells.	2. Endothelium.
	3. Lamina supra-choroidea.	A thin membrane loosely united to the lamina fusca and choroid.	1. Base.	Imperfect lamellæ of a fibro-elastic ground work joining at various angles.
			2. Cells.	Irregular groups of endothelial cells.
	4. Choroid.	A dark brown membrane between the sclera and retina.	1. Stroma layer.	1. Outer layer. 1. Branched pigmented cells. 2. Connective tissue lamellæ. 3. Large blood vessels.
				2. Inner layer. Unpigmented wavy bundles of connective tissue giving a metallic reflex called tapetum fibrosum.
			2. Chorio-capillaris.	A narrow zone of homogeneous matrix in which is embedded a capillary network from short ciliary arteries.
			3. Vitreous lamina.	Inner, homogeneous layer supporting the retinal pigment.
	5. Ciliary body.	The part between the end of the chorio-capillaris opposite the ora serrata behind and the outer margin of the iris in front.	1. Ciliary ring or orbicularis ciliaris.	1. White fibrous tissue. 2. Yellow elastic tissue. 3. Smooth muscle prolonged from the ciliary muscle.
			2. Ciliary processes, seventy in number.	1. Outer row of low pigmented epithelium. 2. Middle connective tissue layer. 3. Smooth muscle arranged meridionally, radially and circularly.
			3. Ciliary muscle.	1. Smooth muscle arranged meridionally, radially and circularly. 2. Connective tissue interlacing with the smooth muscle.

SENSORY SYSTEM.—*Continued.*

ORGAN.	DESCRIPTION.	DIVISIONS.	DESCRIPTION.	SUBDIVISIONS.	STRUCTURE.
6. Iris of the eye.	The contractile colored membrane behind the cornea giving the tint to the eye.	1. Anterior endothelium.	Extension of the corneal cells free from pigment.	1. Cells.	Single layer of polygonal, nucleated, epithelial cells.
				2. Base.	Cement.
		2. Anterior boundary layer.	Modification of the first stratum of the iris stroma.	1. Cells.	Leucocytes.
				2. Base.	Reticular tissue.
		3. Vascular stroma layer.	Chief mass of the iris.	1. Stroma.	Retiform tissue reinforced by blood vessels.
				2. Muscle.	Smooth.
				3. Nerves.	Medullated in the superficial part, non-medullated networks within.
				4. Blood vessels.	The arteries spring from the circulus arteriosus iridis major, pass radially toward the center of the iris near which they form a second ring called the circulus arteriosus iridis minor.
				5. Sphincter pupillæ.	Smooth muscle surrounding the margin of the pupil.
				6. Dilator pupillæ.	Smooth muscle radially arranged.
		4. Posterior boundary layer.	Glassy layer stretching over the posterior surface of the stroma.	Resembling a basement membrane.	Though structureless, it closely resembles elastic tissue in character.
		5. Pigmented layer.	A layer covering the entire pupillary margin ending as a thickened free edge in advance of the plane of the iris.	1. Anterior part.	Spindle cells radially arranged, extending from the ciliary border of the iris to the margin of the pupil. At the ciliary border the cells change their form to polyhedral and are continuous with the low pigment cells composing the corresponding layer of the ciliary processes.
				2. Posterior part.	A thick zone of pigment cells so densely packed that their boundaries and nuclei are very indistinct, the whole resembling one continuous mass of pigment. A delicate membrane—the membrana limitans iridis—covers the posterior surface.
		6. Pupil.	Aperture in the center of the iris.	Circular in form, a little to the inner side of the center of the iris.	
		7. Color of Iris.	The color of the eye depends upon the amount and kind of pigment in the iris.	1. Blue eyes.	Stroma free from pigment.
				2. Light gray eyes.	Pigment in small amount.
				3. Brown eyes.	Pigment in large amount.
				4. Black eyes.	Pigment in very large amount.
				5. Albino eyes.	No pigment even in retinal part of the iris.

SENSORY SYSTEM.—*Continued.*

ORGAN.	DESCRIPTION.	DIVISIONS FROM WITHIN OUTWARD.	DESCRIPTION AND STRUCTURE.		
7. Retina of the eye.	A delicate membrane containing the expanded termination of the optic nerve. It is within the choroid, rests on the hyaline membrane of the vitreous humor, extends forward to the outer edge of the ciliary processes of the choroid where it ends in a border called the ora serrata.	Radial fibers of Müller.	Long neuroglia fibers extending throughout the entire thickness of the retina.		
		1. Internal limiting membrane.	Expanded inner ends of the radial fibers of Müller forming the inner boundary of the retina next to the vitreous humor.		
		2. Layer of nerve fibers.	Axis cylinders of the optic nerve fibers which extend as far forward as the ora serrata.		
		3. Layer of nerve cells.	A single row of multipolar large nerve cells.		
		4. Inner molecular layer.	Reticular tissue of the neuroglia, branches of nerve cells and a few flattened cells.		
		5. Inner nuclear layer.	An inner layer of small multipolar nerve cells and an outer layer of small bipolar nerve cells.		
		6. Outer molecular layer.	Reticular tissue of neuroglia and branches of nerve cells.		
		7. Outer nuclear layer.	Rod granules and cone granules according to their connection with the rods or cones.		
		8. External limiting membrane.	Structureless membrane formed by the expansion of the outer branched ends of the fibers of Müller.		
		9. Layer of rods.	1. Outer segment.		A series of transverse disks which are the seat of the visual purple.
			2. Inner segment.	1. Rod fibers.	Protoplasmic bodies of the visual cells.
				2. Rod granules.	Seat of the nuclei of the visual cells.
		10. Layer of cones.	1. Inner segment.	1. Cone fibers.	Like rod fibers except that they are broader and more regular in form.
				2. Cone granules.	Like the rod granules.
			2. Outer segment.		A series of transverse disks.
		11. Pigment layer.	A single layer of hexagonal epithelium. The outer surface of each cell contains the nucleus. The inner boundary is not well marked for the substance of the cell is here loaded with black pigment and prolonged into fine straight filamentous processes which extend a certain distance between and among the outer segments of the rods and cones.		

SENSORY SYSTEM.—*Continued.* EYE.

DIVISIONS OF THE RETINA AND OTHER PARTS OF THE EYE.	DESCRIPTION.	DIVISIONS.	STRUCTURE.		
1. Macula lutea.	An elliptical yellow spot situated in the axis of the eye ball.	1. Border.	Yellow pigment, retinal layers.		
		2. Center.	See fovea centralis.		
2. Fovea centralis.	A slightly hollow place in the center of the macula lutea.		1. Layers of retina except the rods. 2. Black pigment layer.		
3. Ora serrata.	The anterior border of the retina situated just behind the ciliary processes.	1. End of the optical retina. 2. Serrated edge. 3. End of the two reticula strata. 4. Unusual development of radial fibers of Müller.	1. Pars ciliaris.	Outer layer.	Extension of the retinal pigment only.
			2. Pars iridica.	Inner layer.	Simple columnar epithelium.
4. Optic nerve.	The cerebral nerve which enters the eye ball ⅛ of an inch to the inside of the axis.	1. Connective tissue sheath.	1. Dura mater. 2. Arachnoid. 3. Pia mater.		
		2. Trunk.	Bundles of medullated nerve fibers without neurilemma.		
		3. Fibrous septa.	Connective tissue divisions between the nerve fibers.		
5. Crystalline lens.	A double, convex, transparent, solid body with the anterior surface in contact with the iris and posterior surface with the vitreous body.	1. Lens substance.	1. Lens fibers.	Greatly elongated epithelial cells.	
			2. Lens epithelium.	Single layer of polyhedral cells.	
		2. Lens capsule.	A strong, clear elastic membrane enclosing the lens.		
6. Aqueous humor.	A watery lymph which fills the aqueous chamber between the lens and cornea.				
7. Vitreous humor.	A spherical gelatinous body filling four-fifths of the eye ball and extending from the retina behind to the lens in front.	1. Hyaloid membrane.	Glassy, structureless membrane around the outside.		
		2. Patellar fossa.	Space in front where hyaloid membrane is absent and anterior surface touches posterior capsule.		
		3. Vitreous substance.	1. Fibers.	Connective tissue fibers of great delicacy.	
			2. Cells.	A few leucocytes.	
		4. Central canal.	A canal extending from the optic papilla to lens capsule.		
8. Eyelids.	Two movable portions of integument covering the eye ball.	1. Skin.	Like integument elsewhere.		
		2. Muscle.	Orbicularis palpebrarum.		
		3. Connective tissue.	1. Tendon of the levator palpebræ. 2. Fascia palpebralis containing smooth muscle.		
		4. Tarsal plate.	1. Semilunar plate of dense fibrous tissue. 2. Meibomian glands.		
		5. Conjunctiva.	1. Epithelium, stratified pavement. 2. Tunica propria of connective tissue.		

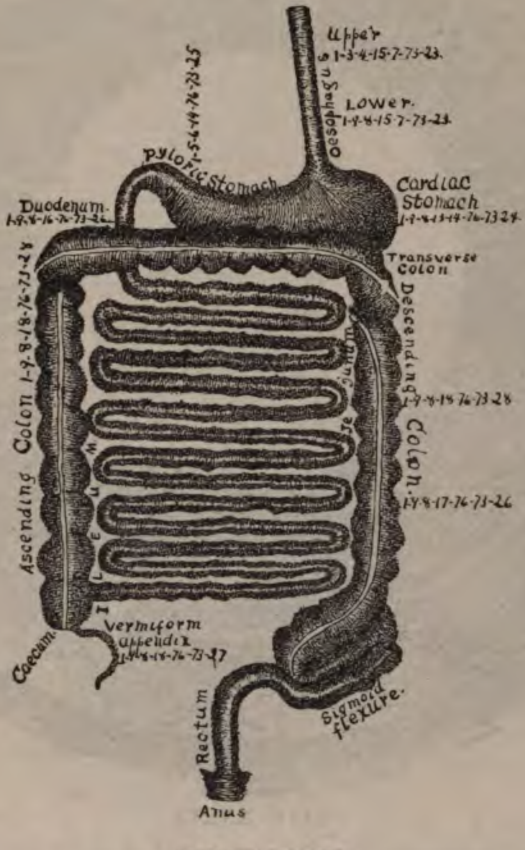


PLATE XXXV.

FOUR-COATED TUBE-MUSCULAR-MOTOR—ALIMENTARY CANAL. (Numbers are model numbers.)

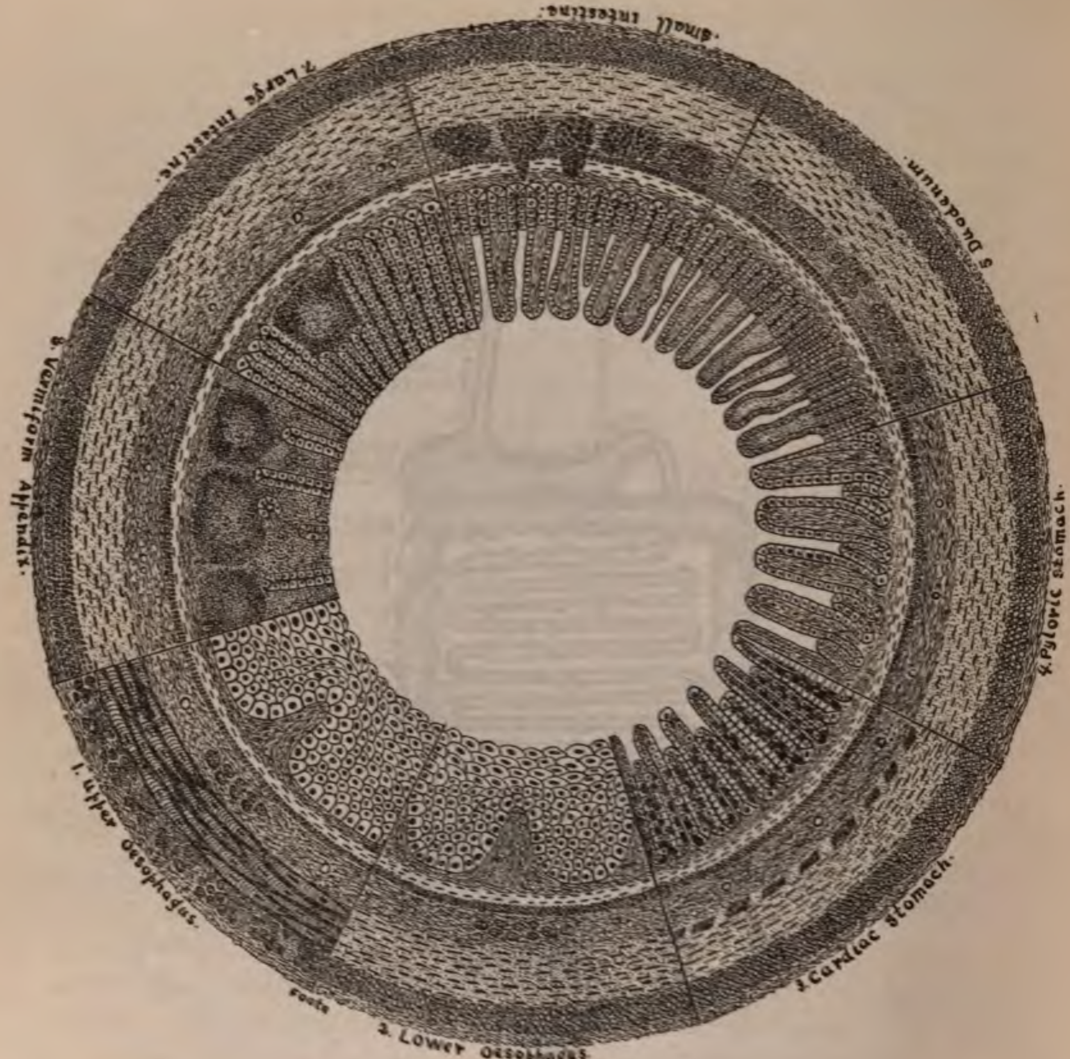


PLATE XXXVI.

EIGHT PARTS OF THE FOUR-COATED TUBE—ALIMENTARY CANAL—IN ONE, SHOWING THE COATS AND LAYERS COMMON TO THEM ALL.

DIAGRAM REPRESENTING THE STRUCTURAL RESEMBLANCES AND DIFFERENCES OF THE EIGHT DIVISIONS OF THE ALIMENTARY FOUR-COATED TUBE.

Examination of it shows that: 1. A connective tissue is common to them all. 2. The muscular coat has two layers, except cardiac stomach which has three. 3. The upper œsophagus only has striped muscle. 4. The subepithelial coat contains secretory glands in two places, viz., œsophagus and duodenum. 5. The muscularis mucosæ is continuous. 6. The epithelium of œsophagus is stratified pavement. 7. The epithelium of cardiac stomach—compound tubular glands with short necks, long bodies lined by chief and parietal cells. 8. Pyloric stomach—compound tubular glands, long necks, short bodies, chief cells. 9. Duodenum—crypts and villi. 10. Small intestine—crypts and villi. 11. Large intestine—crypts. 12. Vermiform appendix—lymphoid tissue and incomplete crypts.

Four Coated Tubes, Muscular Motor (see Plate XXXV, mac., XXXVI, mic.).—These tubes may be formed from three coated tubes by adding to the under side of their epithelial coats one or two very thin layers of smooth muscle called the Muscularis Mucosæ. The alimentary canal is the only tube of this class. This is the most complex tube, for the reason that it has the greatest number of coats and hence the greatest number of functions. The coats are: connective tissue, muscular, sub-epithelial and epithelial. As any one or more of these coats answers the same purpose in any tube in which it occurs, one description will answer for all. It is evident that these coats will have the same functions wherever they are found, that is, supporting, contracting, uniting and secreting.

1. *Connective Tissue Coat.*—This is a thin layer of connective tissue which surrounds the tube, for the most part, from the lower end of the œsophagus to the rectum. This coat of the œsophagus consists of the connective tissue which supports the tube and may or may not be considered as a distinct coat. By means of this coat, in any location, a tube is supported by attachments to the skeleton or to the other structures and provided with a blood and lymph circulation. The outside connective tissue coats of all tubes having such a coat have the same function and hence can be represented by the same model. (See Plate XIII, figs. 1, 73 and 20.)

2. *Muscular Coat.*—This is composed of two layers of muscle throughout the whole length of the alimentary canal except at the cardiac end of the stomach where there are three. In the upper half of the œsophagus the muscle is striped, in the lower half smooth. The alimentary canal is a motor tube because progressive motion of its contents in a certain direction is necessary. This can be accomplished only by a contractile tissue which must be arranged according to some definite plan. In the majority of motor tubes two layers of muscle are sufficient; an external longitudinal and an internal circular. In a very few three layers are found. Of the two layers the external longitudinal by contraction shortens the tube and stiffens it while the internal circular, by waves of contraction from above downward, propels the contents towards the lower end of the tube. In the cardiac stomach, the internal oblique layer of muscle is composed of a few radiating strands over the fundus, the

effect of which is not apparent. Layers of muscle are joined by thin connective tissue which carries small blood vessels, lymphatics and plexuses of nerves. In the pyloric stomach the internal circular layer of muscle is thickened to form the sphincter pylori. The character of the contents of a tube governs the amount of muscle which it contains. The contents of the four coated tube are large. There is no force behind them and, therefore, a well developed muscular coat is provided in order to move the contents from one end of it to the other. The muscular coats of all tubes having more than one layer of muscle have the same function because they have the same tissues arranged in the same manner. This coat then, wherever it occurs, can be represented by general models of various thicknesses indicating the layers. (See Plate XIV, figs. 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13.)

3. *Sub-Epithelial Coat.*—This coat is composed of areolar tissue which joins the muscular and epithelial coats and provides them with blood vessels, nerves and lymphatics. In two places, the œsophagus and duodenum, secreting glands are found. While this coat unites the epithelial and muscular coats, it allows freedom of motion of the former upon the latter on account of its areolar character. It is widest in the stomach and here the epithelial coat is more freely movable than elsewhere. It contains solitary glands, agminated glands and secreting glands. As it is always composed of the same areolar tissue and has practically the same function, it may be represented by models of areolar tissue containing the characteristic structures. (See Plate XIII, figs. 14, 15, 16, 17 and 18.)

4. *Epithelial Coat.*—This coat is also called mucous membrane or mucosa. The term *epithelial* coat is preferred because it suggests *any* secreting function rather than a *mucous* secreting function. It is made up of three parts: a muscularis mucosæ, which is external and composed of two very thin layers of smooth muscle—an external longitudinal and an internal circular; a connective tissue base containing in some places diffuse masses of lymphoid tissue, in other places solitary glands and agminated glands, nerves, blood vessels and lymphatics; lastly, some form of epithelium such as stratified pavement in the œsophagus, tubular glands in the stomach, crypts of Lieberkühn with many goblet cells in the large intestine, crypts of Lieberkühn and villi in the small intestines,

NERVOUS SYSTEM.—*Continued.*

ORGAN.	DIVISION.	DIVISION.	SUBDIVISION.	DESCRIPTION.	STRUCTURE.
Cerebrum continued.	1. Hippocampus major or cornu ammonis.	1. Internal white zone. 2. Middle gray zone. 3. External white zone.	1. Alveus.	Ventricular surface.	Medullated nerve fibers.
			2. Stratum oriens.	Fourth cortical layer.	1. Spindle nerve cells. 2. Nerve fibers.
			3. Stratum cellularum pyramidalium.	Third cortical layer.	Large pyramidal nerve cells whose branches extend into the alveus.
			4. Stratum radiatum.	Branches of third layer.	Branches of the pyramidal cells.
			5. Stratum lacunosum.	Parallel to alveus.	Axis cylinders.
			6. Stratum moleculare.	Vertical and lateral cell branches.	Small pyramidal ganglion cells.
			7. Lamina medullaris involuta.	Outer cortical layer.	Nerve fibers.
		4. Fascia dentata.	1. Nerve fibers. 2. Ganglion cells.	Thickened edge of cortical layer of the cerebrum.	Medullated fibers. 1. Pyramidal cells. 2. Polymorphous cells. 3. Fusiform cells.
	2. Special masses of gray matter.	1. Within the white matter.	1. Corpus striatum. 1. Nucleus caudatus.	Intraventricular portion.	1. Large, multipolar nerve cells. 2. Small, ganglion cells 3. Nerve fibers.
			2. Nucleus lenticularis.	Extraventricular portion.	1. Multipolar nerve cells. 2. Medullated nerve fibers.
			2. Optic thalamus. 1. Inner nucleus. 2. Outer nucleus.	Two unequal divisions of gray matter by white septum.	1. Multipolar nerve cells. 2. Medullated fibers. 3. Ganglion cells alternating with medullated fibers.
			3. Corpus subthalmicum. 1. Cells. 2. Fibers.	Brown stratum of gray matter.	Multipolar cells. Fine medullated fibers.
			4. Corpora quadrigemina. 1. Anterior. 2. Posterior.	Four bodies on the dorsal aspect of the sylvian duct.	1. Various shaped nerve cells. 2. Medullated fibers. 3. Small, multipolar cells. 4. Large, multipolar cells.
		2. Along the floor of third ventricle.	1. Lamina cinereum.	Between chiasm and the corpus callosum.	1. Ganglion nerve cells 2. Special bundles of nerve fibers.
			2. Tuber cinereum.	Part of the floor of the third ventricle.	
			3. Infundibulum.	Hollow conical process of the tuber cinereum.	
			4. Corpora albicantia of posterior perforated space.	Two gray nuclei within white fibers.	

lows that connective tissue will be essential to the composition of them all. Outside coats, sub-epithelial coats, epithelial bases and intermuscular layers, which together form the framework, are all composed of this tissue and occupy the same relative situations in the walls of tubes. This fact facilitates their construction.

2. All tubes of more complex structure than the one coated, and even a few of these, must have some form of motor apparatus because their contents must, of necessity, be moved and they cannot be moved without a motor power. The motor apparatus is composed of the contractile tissues—muscle and ciliated cells. These will vary in distribution according to the work to be done. The ciliated cells are found in the lining while muscle forms the surrounding layers and coats. All large tubes have such an apparatus and hence their construction is further simplified.

3. Each tube must have a form of tissue which is capable of rearranging chemical elements and thereby producing such chemical products as secretions, excretions and the complex variety of chemical bodies which account for vital phenomena. This most complex form of all cell actions is provided by some form of epithelium. There are, perhaps, no cells in the body having a greater range of capacity than epithelial cells. The life and continuation of the living body are possible only because these cells stand between the insoluble foods of its environment and the body cells, in the capacity of chemical transformers by the action of which chemical compounds are made soluble, dialyzable and reconstructive and their chemical elements are qualified to succeed their predecessors in the important rôle of protoplasmic constituents. We know, therefore, that all tubes will have epithelium. In cross sections of tubes the nervous system does not appear to any appreciable degree; hence we see that connective tissue, muscle and epithelium are the three visible tissues which will enter into the formation of tubes in proportion to their requirements. The plan according to which they are arranged will naturally be the same in all, that is, muscle and epithelium enclosed in a framework of connective tissue or resting upon it as a foundation. Practically, then, in tube formations we are dealing with three tissues as far as the microscope is concerned—connective tissue, muscle and epithelium. This may be understood from the following outline:

OUTLINE OF THE THREE TISSUES SEEN IN TUBE STRUCTURES.

One Layer Tube. Non-motor.

Organs.	Epithelium.	Muscle.	Connective Tissue.
Capillaries.	Simple pavement.		

One Coated Tubes. Non-motor.

Organs.	Epithelium.	Muscle.	Connective Tissue.
Tubuli uriniferi.	Simple rodded, cubical.		Basement membrane.
Tubuli seminiferi.	Stratified embryonic.		Basement membrane.
Crypts of Lieberkühn.	Simple columnar.		Basement membrane.
Serous membranes.	Simple pavement.		Fibrous tissue in layers.
Graafian follicle.	Stratified embryonic.		Connective tissue.
Very small ducts.	Simple cubical.		Basement membrane.
Acini of secreting glands.	Simple polygonal.		Basement membrane.
Vestibule, utriculus.	Simple cubical, hair cells.		
Sacculus of ear.	Sustentacular cells.		Dense connective tissue.
Semi-circular canals.	Simple cubical, hair cells, sustentacular cells.		Connective tissue.
Cochlea.	Endothelium, pillar cells, sustentacular cells.		Connective tissue.
Olfactory nasal mucosa.	Olfactory cells and sustentacular cells.		Connective tissue.
Skin.	Stratified pavement.		Connective tissue with glands.
Hair follicle.	Stratified pavement.		Connective tissue.
Lacrimal sac.	Simple pseudo-stratified columnar.		Connective tissue with glands.
Nasal duct.	Stratified pavement.		Connective tissue with glands.

One Coated Tube. Ciliary-motor.

Organs.	Epithelium.	Muscle.	Connective Tissue.
Nasal duct.	Stratified ciliated.		Connective tissue with glands.
Tympanum of ear.	Simple pseudo-stratified ciliated.		Connective tissue.
Eustachian tube.	Simple pseudo-stratified ciliated and stratified ciliated.		Connective tissue.
Respiratory nasal mucosa.	Stratified ciliated.		Connective tissue.

Two Coated Tubes. Ciliary-motor.

Organs.	Epithelium.	Muscle.	Connective Tissue.
Trachea and large bronchi.	Stratified ciliated.		Connective tissue with C-shaped rings of hyaline cartilage and secreting glands.

OUTLINE OF THE THREE TISSUES SEEN IN TUBE STRUCTURES.—*Continued.*

THREE COATED TUBES. MUSCULAR-MOTOR.

ORGANS.	EPITHELIUM.	MUSCLE.	CONNECTIVE TISSUE.
Vagina.	Stratified pavement.	Two layers, smooth.	Connective tissue.
Upper ureter.	Stratified transitional.	Two layers, smooth.	Connective tissue.
Lower ureter.	Stratified transitional.	Three layers, smooth.	Connective tissue.
Urinary bladder.	Stratified transitional.	Three layers, smooth.	Connective tissue.
Gall bladder.	Simple columnar.	Two layers, smooth.	Connective tissue.
Small artery.	Simple pavement.	One layer, smooth.	Connective tissue.
Small vein.	Simple pavement.	One layer, smooth.	Connective tissue.
Large duct.	Simple columnar.	Two layers, smooth.	Connective tissue.
Seminal vesicles.	Simple pseudo-stratified columnar.	Two layers, smooth.	Connective tissue.
Corpus spongiosum.	Stratified columnar.	One layer, smooth.	Connective tissue.
Vas deferens.	Stratified columnar.	Three layers, smooth.	Connective tissue.

THREE COATED TUBES. MUSCULAR-CILIARY MOTOR.

ORGANS.	EPITHELIUM.	MUSCLE.	CONNECTIVE TISSUE.
Fallopian tubes.	Simple ciliated.	Two layers, smooth.	Connective tissue.
Uterus.	Simple ciliated.	Three layers, smooth.	Connective tissue.
Epididymis.	Stratified ciliated.	Two layers, smooth.	Connective tissue.
Medium and small bronchi.	Stratified ciliated.	One layer, smooth.	Connective tissue, glands, cartilage.
Vas deferens.	Stratified ciliated.	Three layers, smooth.	Connective tissue.

FOUR COATED TUBES. MUSCULAR-MOTOR.

ORGANS.	EPITHELIUM.	MUSCLE IN MUSCULAR COAT.	MUSCLE IN EPITHELIAL COAT.	CONNECTIVE TISSUE.
Upper œsophagus.	Stratified pavement.	Two layers, stratified voluntary.	One layer, smooth.	Connective tissue.
Lower œsophagus.	Stratified pavement.	Two layers, smooth.	One layer, smooth.	Connective tissue.
Cardiac stomach.	Simple columnar.	Three layers, smooth.	Two layers, smooth.	Connective tissue.
Pyloric stomach.	Simple columnar.	Two layers, smooth.	Two layers, smooth.	Connective tissue.
Duodenum.	Simple columnar.	Two layers, smooth.	Two layers, smooth.	Connective tissue.
Jejunum. Ileum.	Simple columnar.	Two layers, smooth.	Two layers, smooth.	Connective tissue.
Large intestine.	Simple columnar.	Two layers, smooth.	Two layers, smooth.	Connective tissue.
Vermiform appendix.	Simple columnar.	Two layers, smooth.	One incomplete layer.	Connective tissue.

THE FIVE CIRCULATIONS.

1. Blood.

1. Systemic. See Plate XXXVIa.	Aorta.	Arteries. Capillaries. Veins.	Venæ Cavæ.	Right auricle. Right ventricle. Pulmonary artery. Pulmonary veins. Left auricle. Left ventricle.	Aorta.

	Respiratory.	Nutritive.	
2. Pulmonary. See Plate XXXVII.	Right ventricle. Pulmonary artery. Pulmonary capillaries. Pulmonary veins. Left auricle. Left ventricle.	Bronchial artery.	Bronchial veins. Pulmonary veins.

	Veins which Form the Portal.	Functional.		Nutritive.	
3. Portal. See Plate XXXVIII.	1. Gastric. 2. Splenic. 3. Superior mesenteric. 4. Inferior mesenteric.	Portal.	1. Interlobular veins. 2. Capillaries. 3. Interlobular veins. 4. Sublobular veins. 5. Hepatic veins. 6. Inferior vena cava.	Hepatic artery.	Hepatic veins.

	Functional.		Pressure Reducing.	
4. Renal. See Plate XXXIX.	Long.	1. Incomplete arch. 2. Interlobular artery. 3. Vasa afferentia. 4. Malpighian tuft. 5. Vasa efferentia. 6. Venous plexus. 7. Interlobular vein. 8. Venous arch. 9. Renal vein. 10. Inferior vena cava.	Short.	1. Renal artery. 2. Incomplete arch. 3. Arteria recta. 4. Capillaries. 5. Venæ rectæ. 6. Venous arch. 7. Renal vein. 8. Inferior vena cava.

	Sources.	Medium Vessels.	Large Trunks.	Exits.
2. Lymph.	1. Lymph spaces. 2. Perivascular spaces. 3. Serous cavities. 4. Lacteals.	1. Lymph capillaries. 2. Lymph vessels.	Thoracic duct. Right lymphatic trunk.	Left subclavian vein. Right subclavian vein.

NERVOUS SYSTEM.—*Continued.*

Organ.	Divisions.	Subdivisions.	Description.	Structure.
6. Spinal cord.	1. Membranes.	1. Dura mater.	An external, dense membrane separated from the walls of the bony canal by a space containing areolar tissue, fat and extensive plexuses of veins.	White fibrous tissue with very few elastic fibers and covered with endothelium.
		2. Arachnoid.	A thin, delicate membrane separated from the pia mater by a space called the subarachnoid space containing the cerebro-spinal fluid.	
		3. Subarachnoid trabeculæ.	Partitions of the subarachnoid space by prolonged extensions from the arachnoid to the dura mater.	
		4. Ligamentum denticulatum.	Narrow bands between the anterior and posterior nerve roots attached by their inner edges to the pia mater and by their outer denticulated edges to the dura mater.	
		5. Pia mater.	A delicate, vascular membrane investing the cord and dipping down into its fissures.	
		6. Filum terminale.	Prolongation of the pia mater downward enclosing the central canal and a little gray matter at its upper end.	White fibrous tissue and a few nerve cells.

		Divisions.	Further Divisions.	Subdivisions.	Location.	Description.	Structure.
6. Spinal cord.	2. Nervous matter.	1. Peripheral white matter.	1. Fissures.	1. Anterior.	Median.	Short, wide and does not reach gray commissure.	
				2. Posterior.	Median.	Long, narrow and does reach gray commissure.	
			2. Columns.	1. Anterior.	Between anterior horns.	1. Direct pyramidal tract. 2. Anterior radicular zone.	1. Nerve fibers of varying sizes and neuroglia.
				2. Lateral.	Between anterior and posterior horns.	1. Ascending lateral tract. 2. Descending lateral tract. 3. Mixed lateral tract. 4. Crossed pyramidal tract. 5. Direct cerebellar tract.	
				3. Posterior.	Between posterior horns.	1. Lateral (Burdach). 2. Median (Goll).	
			3. Commissure.	White.	Floor of the anterior fissure.	Narrow, transverse band.	Nerve fibers.
		2. Central gray matter.	Two symmetrical halves joined together by a gray commissure.	1. Anterior horns.	Wide and do not reach the surface except by roots.	1. Nerve cells.	Multipolar.
				2. Gray commissure.	Partuniting gray halves. Contains central canal.	2. Nerve fibers.	1. Medullated. 2. Non-medullated.
						3. Substantia spongiosa.	Modification of the neuroglia.
				3. Posterior horns.	Narrow and continue to the surface.	4. Substantia gelatinosa.	Ground substance around central canal.

NERVOUS SYSTEM.—*Continued.*

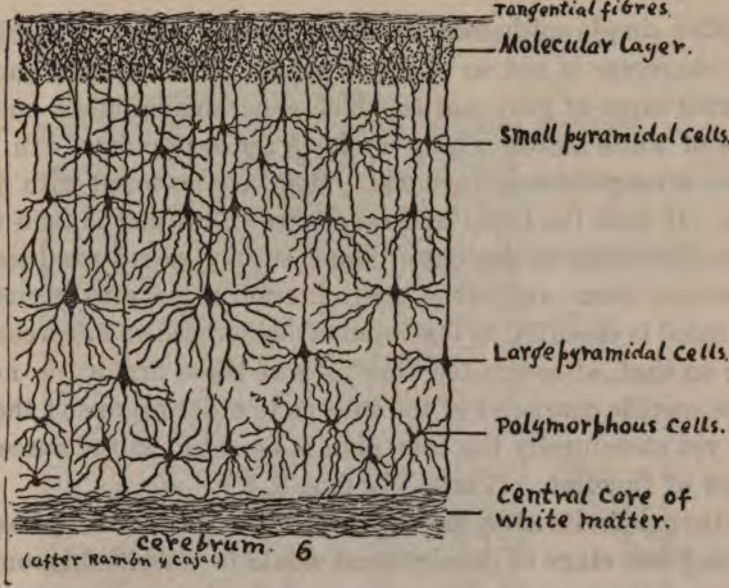
Organs.	Divisions.	Description.		Structure.	
7. Pituitary body or hypophysis cerebri.	1. Anterior oral lobe.		Larger, darker than the posterior. For some time remains connected with the oral cavity. Later its connection atrophies and disappears leaving the anterior lobe separated from the buccal cavity. The single primary tube by division becomes the tubular acini.	1. Tubules.	1. Basement membrane. 2. Polyhedral epithelium.
				2. Framework.	Fibrous and elastic tissues.
				3. Lumina.	Colloid matter.
	2. Posterior cerebral lobe.		Small and of a distinctly nervous type in the lower animals. In the higher this character is lost, the lobe remaining rudimentary. Outgrowth of the primitive brain.	1. Framework.	Fibrous and elastic tissues.
				2. Nerve elements.	Small pyramidal nerve cells.
				3. Cavity.	Lined by ciliated columnar epithelium.
8. Pineal gland or epiphysis cerebri, the remains of a primitive eye.	1. Alveoli.		Tubular compartments held together by a framework.	1. Basement membrane.	
				2. Epithelium.	Polyhedral.
				3. Brain sand.	Calcium carbonate. Calcium phosphate. Magnesium phosphate. Ammonium phosphate.
				4. Corpora amylacea.	Round masses with concentric striation. Respond to starch tests.
	2. Septa.		Connective tissue holding together the alveoli.	Fibrous and elastic tissues.	
9. Olfactory lobe.	1. Tractus olfactorius.	1. White matter.	An enclosing sheath or ring of nerve fibers.	Medullated nerve fibers.	
		2. Neuroglia.	Indicates the position of a former lumen.		
		3. Gray matter.	An oval area richest in the dorsal part of the tract.	Same as cerebral cortex.	
	2. Bulbus olfactorius.	1. White matter.	A flat ring of longitudinal nerve fibers.	Medullated nerve fibers.	
		2. Neuroglia.	Indicates position of a former lumen.		
		3. Stratum granulosum.	Large pyramidal cells with branches and axis cylinders.	Nerve cells.	
		4. Olfactory glomeruli.	Dense tufts of the terminal ends of the processes of the pyramidal cells.	Protoplasmic branches of nerve cells.	
		5. Olfactory nerve fibers.	Arise in the cells of the Schneiderian membrane from whence they pass to the cerebrum.	Non-medullated nerve fibers.	

ORGANS WHICH APPARENTLY ARE NOT TUBULAR.

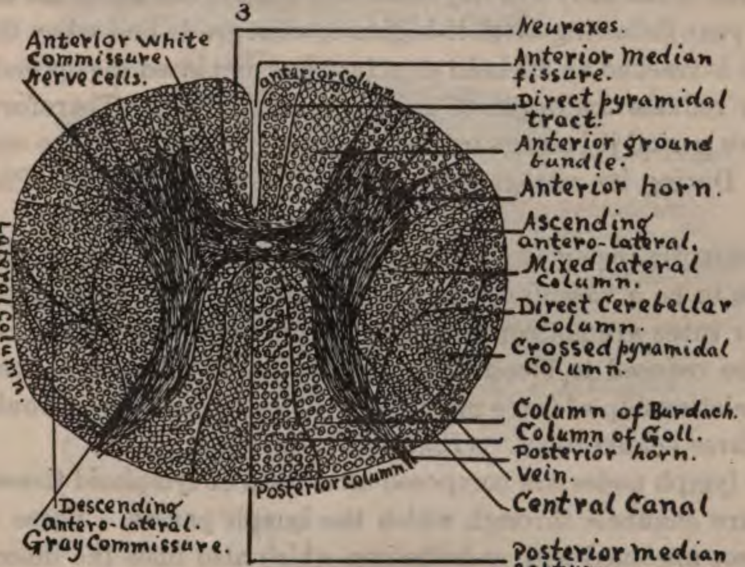
Organs.	Divisions.	Structure.	
1. Spleen. Plate XLI, Fig. 1.	1. Capsule.	Connective tissue mixed with smooth muscle surrounding the organ and extending into its interior as a framework.	
	2. Trabeculæ.	Prolongations from the capsule which unite by processes in the interior and form the framework.	
	3. Malpighian corpuscle.	Spherical or cylindrical masses of lymphoid tissue surrounding the branches of the splenic artery. In section the artery appears in the center or at one side of the lymphoid mass.	
	4. Spleen pulp.	A stroma of reticular tissue continuous with the trabeculæ. Red blood cells and leucocytes in large numbers. Large, round, amœboid cells sometimes containing pigment granules and red blood cells. Nucleated red blood cells.	
	5. Splenic artery.	The artery and vein do not connect directly by capillaries. The blood passes out of the fine arterial branches and circulates in spaces between the cells of the pulp and then finds its way into the branches of the splenic vein.	
2. Adrenals. Plate XLII, Fig. 4.	1. Capsule.	Connective tissue and smooth muscle.	
		Structural Units.	Description.
	2. Cortex.	1. Zona glomerulosa.	Oval masses of cells.
		2. Zona fasciculata.	Long cylindrical masses of cells.
		3. Zona reticularis.	Anastomosing cords of pigmented cells.
	3. Medulla.	1. Cords and networks.	Cords and networks of polygonal cells.
		2. Ganglionic cells.	1. Nerve cells. 2. Non-medullated nerve fibers.

ORGANS WHICH APPARENTLY ARE NOT TUBULAR.—*Continued.*

Organ.	Divisions.	Structure and Description.
4. Thymus. Plate XLI, Fig. 2.	1. Capsule.	Connective tissue surrounding the organ.
	2. Lobes.	Larger divisions of the organ united by connective tissue.
	3. Lobules.	Smaller divisions of the lobes united by connective tissue. Follicles. 1. Cortex. Densely packed with leucocytes. 2. Medulla. Loosely packed with leucocytes. Concentric corpuscles of Hassall. Remains of early epithelium.
5. Tonsil.	1. Surface.	Stratified pavement epithelium perforated by twelve to fifteen orifices which lead into crypts.
	2. Framework.	White fibrous intermixed with yellow elastic.
	3. Spherical bodies.	Ten to eighteen round masses of lymphoid tissue arranged around the walls of the crypts.
	4. Crypts.	Pockets formed by the surface dipping down into the interior.
6. Carotid gland. 7. Coccygeal gland.	At the upper end of the common carotid and in front of the apex of the coccyx are two small glandular looking bodies composed almost entirely of plexuses of blood vessels derived from the carotid and middle sacral arteries—the whole is invested by connective tissue. The blood plexuses are covered by one or more layers of granular, polygonal cells.	



Cerebrum.
(after Ramón y Cajal)



Spinal Cord.

Organs which apparently are not tubular.

PLATE XL.

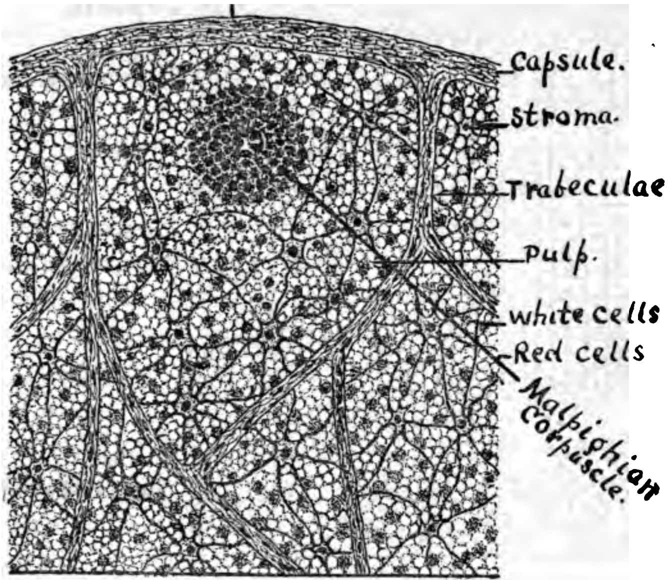
DIAGRAMS OF BRAIN AND SPINAL CORD.

lined with a simple epithelium like certain other tubes. Functionally the tubular character is not so clearly marked. The brain is composed of an external layer of gray matter which generates impulses and an internal core of white matter which conducts those impulses. In the spinal cord this arrangement is reversed. Both are enclosed with a covering of bone. If both the brain and cord were solid, that is, had no central canal, an increased or decreased blood supply would produce pressure upon nervous tissue and cause a termination of nervous phenomena. A central canal is essential to the volumetric increase and decrease of these organs; so that, although the functions of these organs do not depend upon the specific character of the tube as in other organs of the five tube classes, yet structurally the tube plan is essential to the successful performance of function. (Plate XL, figs. 3, 6.)

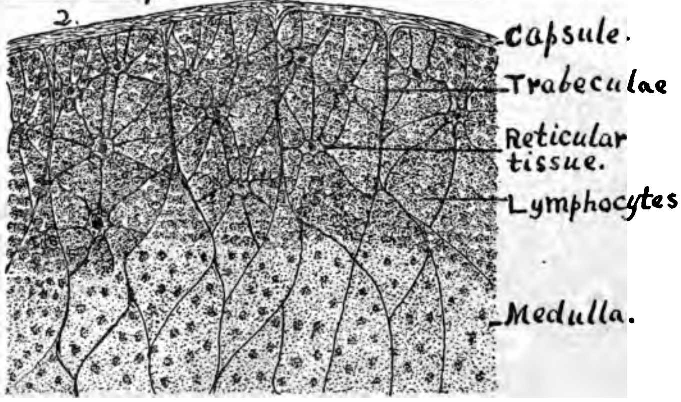
The thymus in its early development is almost like an epithelial gland and during that stage of development would be classified among the tube structures of the body like any other true gland: but about the end of the second year following birth it begins to retrograde and when the age of puberty is reached an adenoid structure has displaced the epithelium and atrophy reduces the organ to an inactive condition. Therefore during its active period it belongs to the secreting glands and to the one coated tubes. During its retrogressive period it is not tubular. (Plate XLI, fig. 2.)

Apparently the spleen does not belong to the tube organs. However it seems to be a vascular body structurally and functionally, for if its vascular tubes are not considered in its plan of structure the remaining parts are reduced to blood cells. Its trabeculæ of smooth muscle suggest a relationship of force pump to the liver and the spleen would belong to the three coated tubes. (Plate XLI, fig. 1.)

The lymph nodes are composed of masses of lymphoid tissue around which are channels through which the lymph passes. These channels or sinuses are lined with endothelium which also lines the inner surface of the capsule and outer surface of the trabeculæ; so that the channels are widened parts of the lymph vessels within the nodes. This places them under the one-layer tubes. As far as function is concerned the parts outside of the channels are reduced to the functions of lymphoid tissue or leucocytes. (Plate XLII, fig. 5.)



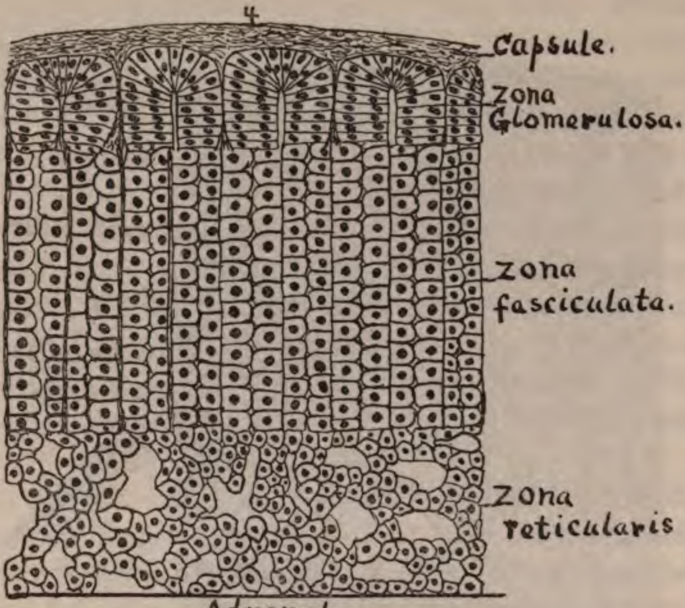
Spleen



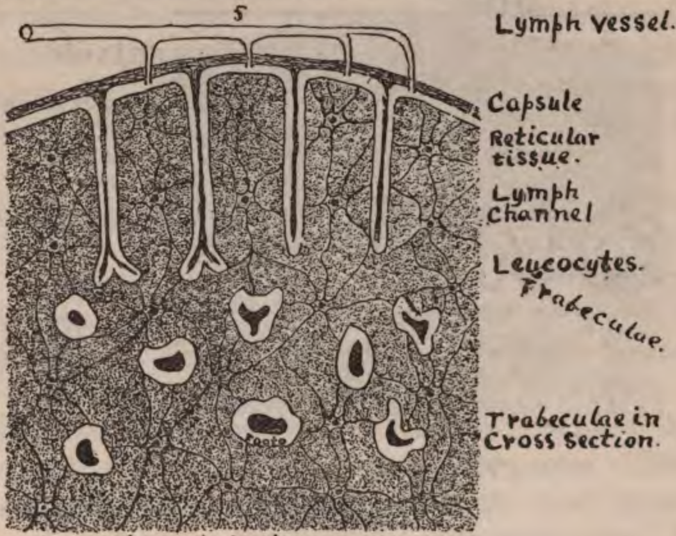
Thymus.

PLATE XLI.

DIAGRAMS OF SPLEEN AND THYMUS GLAND.



Adrenal.



Lymph Node.

PLATE XLII.

Diagrams of the Adrenals and Lymph Nodes.

The adrenals are composed of cells arranged in different ways according to the zones which characterize the structure. A tube plan is not sufficiently apparent in these organs to place them under a tube system. (Plate XLII, fig. 4.)

Thus a general survey of the animal body and its contents convinces one that the tube is a fundamental structure. It must be taken into account in the pursuit of anatomical, histological or physiological investigations. If we study such subjects without bearing constantly in mind the tube in all its variations and purposes we will study them separated from their actual connections with the systems or organs as they really occur. In most instances, if not in all, the phenomena which appear are due to tube influences. In thinking of the functions of the viscera we are obliged to associate together both the tubular structures and the activities of the cells of these structures. For instance, if we think of some secretion and omit the presence of the tube, we simply think of the production of a chemical substance which has no means to direct it to any fixed point. We must, therefore, leave it to be dissipated without serving any useful purpose. As liquids flow in the direction of least resistance, the presence of tubes is not only essential to direct them, but also, by cell activities of their own, to add or subtract from the original liquids and thereby to increase their efficiency. Perhaps all secretions are modified in character by their progress along the tubes which provide for their means of escape and are ineffectual until acted upon by the whole length of tube from beginning to end.

Again the non-motor and motor characters of tubes are essential to our understanding of the disposition of products after they are once formed. The body products are manufactured for a definite purpose and that purpose is defeated without the presence of some motor apparatus in those tubes in which motion of contents is required and the absence of such apparatus in those tubes in which motion of contents is not required. It is necessary to think of all tubes as living tubes and not as lifeless conduits. Tubes resemble each other, since they are often engaged in the same business. Their structures are similar and they can be constructed by means of similar parts, of which they are all composed. This act of construction supplements the mental act which is required in their analysis.

CONSTRUCTIVE DIAGRAM.

In the large, curvilineal, constructive diagram which follows, the five classes of tubes are represented by five concentric circles. In these circles may be found drawings of microscopic sections of nearly all of the tubular organs of the body—sixty-five in number. The circular plan of the diagram suggests the circular character of transverse sections of tubes. By arranging the microscopic sections of all of the organs of any class of tube, side by side, in one circle, the number of organs, the layers and coats in common, the structural characteristics and the plan of construction may all be readily seen and understood. It will be noticed that the largest circle is the circle of the one coated tubes. It comprises the largest number of organs, thirty-five in number, and these organs are mostly the small tubes, chemical in function, non-motor in character, which constitute the secretory, excretory, and sensory organs. Microscopic sections of structural and functional units of many of these organs are very much alike in appearance. Thus a cross section of a single acinus of one secreting gland is very much like a similar section of an acinus of any other secreting gland. If we take acini from all of the secreting glands of the body and place them side by side the differences between them are not always sufficiently apparent to enable one to distinguish, without doubt, one gland from another. For this reason many of the sections in the circle of the one coated tubes closely resemble each other. Next in numerical importance and therefore in size is the circle of the three coated tubes. It comprises nineteen muscular-motor and muscular-ciliary motor tubes. These tubes are the large tubes of blood supply for the viscera, of gaseous income and outgo for the lungs, of outgo for the chemical products of glands and of exit for the products of conception in the female generative tract. Next in numerical importance and size is the circle of the four coated tube. It comprises the eight parts of the alimentary canal which can be identified microscopically. The tube, as a whole, is muscular-motor. The functions of digestion and absorption are performed by the small one coated tubes which enter into the formation of its lining.

Next in numerical importance and size is the circle of the two coated tubes. It comprises only two organs—trachea and large bronchi.

Rings of hyaline cartilage distinguish this tube from the one coated tubes and supply the means by which open tubes are maintained. These tubes are ciliary-motor and the only large tubes with no muscular coat. The next in numerical importance and size is the circle of the one layer tubes described around the common center of all the circles. It comprises all the capillaries, but as these are all alike in structure and function they may be considered as one organ. These tubes are nonmotor and the simplest in structure of all the tubes of the body. Thus the diagram displays the numerical importance of the five classes of tubes. That class of tube which comprises the greatest number of organs is naturally the most prominent in the welfare of the whole body, and this will be inferred from the number of chemical tubes in the one coated circle. In fact the animal body seems to be a colony of secreting glands composed of myriads of chemical tubes the products of which are essential to the continuation of life. It also indicates the mechanical importance of the tubes of income and outgo which serve in the capacity of carriers to and from the chemical tubes as may be seen in the three coated circle. It further indicates the importance of a combination of chemical and mechanical tubes in one as seen in the four coated tube. It indicates the value of a two coated tube as a functional tube; since it comprises only two organs. Lastly, it indicates the simple structure of the one layer tubes. At the left of each microscopical section are the model numbers which, arranged in the order of their occurrence from below upward constitute the building plan. The outlines of the two leaves of the accompanying case correspond in numbers and arrangements with the drawings of the diagram; so that the diagram, outlines and models furnish a working system of tubular construction. As all of the microscopic sections of the tubular organs of each class are placed side by side in one circle a good opportunity is afforded for comparisons in structure. A glance is sufficient to show differences and resemblances. It will be noticed that the differences are, for the most part, in the linings and the resemblances are in the coats external to the linings.

That the only tube in the body having a coat of striped voluntary muscle is the upper œsophagus.

That the muscular coats in other situations are smooth muscle.

That the majority of muscular coats have two layers of muscle—viz., external longitudinal and internal circular.

That the following tubes have coats of three layers of muscle: cardiac stomach, uterus, lower ureters, bladder, vas deferens.

That the following tubes have coats of one layer of muscle: small arteries, veins, lymphatics, medium and small bronchi.

That in muscular coats of three layers the external and internal are longitudinal, the middle circular.

That in muscular coats of one layer the muscle is always circular.

That all large tubes, excepting trachea and large bronchi have muscular coats.

That small tubes have no muscular coats.

That secreting glands are found beneath the epithelial coats of the following ten organs: œsophagus, duodenum, medium bronchi, small bronchi, trachea, large bronchi, nasal duct, lacrimal sac, tympanum of ear, skin. The conclusion, therefore, is that secreting glands do not occur in the walls of the majority of tubular organs.

That in most mucous membranes mucus must be produced by mucous cells of the epithelial coats.

That the structure of all of the organs of each class of tube is essentially the same.

That all tubes have an epithelial coat and all, excepting the one layer tubes, have additional coats according to the function performed.

That the five classes of tubes are developed from the one layer tube by tissue additions. Thus:

1. One layer tube—epithelium.
2. One coated tube—epithelium plus a base.
3. Two coated tube—one coated tube plus cartilage.
4. Three coated tube—one coated tube plus a muscular coat.
5. Four coated tube—three coated tube plus a muscularis mucosæ.

That all tubes are motor or non-motor.

That chemical tubes are non-motor.

That mechanical tubes are motor.

That there are two forms of motor apparatus, viz., cilia and muscle.

The diagram, therefore, calls our attention to a certain class of facts which we are likely to overlook in a study of separate sections and presents to the mind a picture of correlated parts which is very important.

SECTION 3

TECHNIQUE

The Preparation of Normal Tissues.

Unless distinguished by the presence of some normal pigment, protoplasm, in its various forms, is nearly colorless. The differences between one form and another are not sufficiently marked to enable one to identify them as they appear under the microscope without considerable experience. The examination of tissues immediately following their removal from the body reveals them in their natural state and doubtless is the best method to pursue; but in such specimens slight differences in protoplasmic densities are about the only means by which parts can be identified and the detection of these differences requires a much wider experience in microscopic work than most students have had. Some preparation of normal tissues is, therefore, necessary in order to bring before the eye the different parts which are under observation and, furthermore, to preserve them for future study. The preparation comprises several processes, each one of which is essential to the next one in succession. The processes may be outlined and employed in the order given below.

1. Killing, Fixing, Hardening,
2. Decalcification,
3. Dehydration,
4. Infiltration,
5. Embedding,
6. Cutting,
7. Staining,
8. Mounting.

Killing, fixing and hardening: These three processes are usually accomplished by the same means. The object, in all cases, is to exhibit tissues in a condition which approaches the natural as nearly as possible. The more rapidly cells are killed the less liable are they to undergo decomposition changes which evidently must begin as soon as metabolism ceases. No one has ever seen a living cell as it actually exists with its subtle chemical and mechanical activities in operation. No one has, therefore, an adequate knowledge of what is called its natural or normal existence. The cells which we see under the microscope are merely the architectural structures within which a vast performance of unceasing intercellular substances are sufficiently contrasted with their surroundings to make their identification possible. This is accomplished by coloring them with some staining solution which is selective in its action on account of the variations in the chemical elements of both structures and solutions. It would, doubtless, be better if staining processes could be abandoned and tissues examined just as they come from the body; but, at the present time, this is hardly practical, especially with beginners. The usual staining formulæ may be found in the outlines.

Mounting: By this process sections, prepared as above indicated, are placed upon glass slides, enveloped in Canada balsam or some other suitable material and covered by a cover glass.

The satisfactory study of microscopical structures of the body depends largely upon good, clear, well-stained sections. A poor specimen leads one into false impressions or into none at all and if we are compelled to derive our knowledge from it, that knowledge is quite likely to be modified by imagination and conjecture. The field of the microscope is small, especially under high powers, and moving the section about upon the stage in order to see all parts of it produces a moving picture which is not calculated to establish lasting impressions. Such kinodrome effects defeat the very purposes of our investigations.

In the following outlines the ordinary processes and formulæ employed in the preparation of normal tissues are given, in a concise form, to facilitate the selection of suitable reagents. They are given in the order of use, beginning with the killing, fixing, etc., and ending with the mounting of sections on slides.

The Preparation of Normal Tissues.

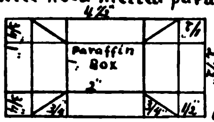
Processes.	Reagents.	Formulae.	Guide in the Selection of a Reagent.
1. Fixing and Hardening.	1. Müller's Fluid.	Potassium Bichromate .... 2.5 grams Sodium Sulphate .... 1 Water .... 100 cc	Lig. nuchae, eye, ganglia, kidney, liver, spleen, tongue. Harden six to eight weeks. Change often.
	2. Orth's Fluid.	Potassium Bichromate .... 2.5 grams. Sodium Sulphate .... 1. ,, Water .... 100 cc. Formaldehyde 40% aq. Solution .... 10 cc Add the Formaldehyde Sol. to the Bichromate at the time of using.	May be used for all tissues. Harden four to six days. Moderate heat hastens the process. Change the Solution once. One of the best of the hardening fluids.
	3. Zenker's Fluid.	Potassium Bichromate .... 2.5 grams. Sodium Sulphate .... 1. ,, Corrosive Sublimate .... 5. ,, Glacial acetic acid .... 5 cc Water .... 100 cc. Add the Acid at time of using.	May be used for all tissues. Rapid. Harden small pieces 24-48 hours. Large pieces several days. Remove precipitate of mercuric salt by addition of 0.5% Tinct. Iodine to the alcohol in which the tissues are preserved
	4. Formaline.	Formaldehyde 40% aq. Sol. .... 10 cc Sodium Chloride 0.75% aq. Sol. .... 90 cc	May be used for all tissues. Rapid. Best for nervous tissue.
	5. Rabl's Solution.	Chromic Acid 0.33% aq. Sol. .... 200 cc Formic Acid .... 5 Drops. Add the Formic Acid at the time of using.	Alimentary canal, embryos, larynx, trachea, lungs, uterus, bladder, ureters, ovaries, smooth muscle. Rapid. Good.
	6. Flemming's Solution.	Osmic Acid 2% aq. Sol. .... 8 cc Chromic Acid 1% aq. Sol. .... 30 cc Glacial acetic acid .... 2 cc Mix as needed.	Penetrates slowly. Has no value in large pieces. Best for study of Karyokinesis. Harden very small pieces 24 hours to 3 days.
	7. Alcohol	70%, 80%, 95%, 98%	Skin, tendon, glands, striped muscle, Harden in the successive grades to prevent shrinkage. Few hours in each sufficient for small pieces.
	8. Osmic Acid.	0.5% aq. sol.	Best for nerve fibers. Treat one to two days.
2. Washing.	1. Water.	After hardening in Bichromate or Marcuric Solutions, tissues should be placed in water for the purpose of removing the color and salts which have been deposited during the process. As a rule it is better to omit the washing process in nervous tissue which has been hardened in Müller's fluid and transfer at once to alcohol.	

Preparation of Normal tissues.

Processes.	Reagents.	Formulae.		Method.
3.Decalcification.	1.Nitric Acid.	Nitric Acid ------ 5 cc Water ---------- 100 cc Change each day for four days. wash. Harden in alcohol.	1.Bone ...	small pieces should be placed in the decalcifying solution and remain until soft. wash until reagent is removed and then harden in alcohol. Phloroglucin protects, the acid decalcifies.
	2.Phloroglucin and Nitric Acid.	Phloroglucin ..... 1 gram. Nitric Acid ...... 5 cc Alcohol .... 70 cc Water ---------- 30 cc Rather slow. Wash. Harden in alcohol. gives good results.	2.Calcareous Tissues.	Harden in Zenker, orth or alcohol. Wash. Place in the decalcifying solution until soft. Wash until reagent is removed and then harden in alcohol.
	3.Picric Acid	A Saturated aqueous Solution with an excess of crystals. Slow. Months required. Decalcifies and hardens at the same time.		
4.Dehydration.	1.Alcohol.	The removal of water from all tissues, which have been hardened or washed, is necessary in order that infiltration may follow.		

	Materials.	Preparation	Method.
5.Infiltration.	1.Celloidin.	Fill a large mouthed bottle ⅔ full of a mixture of equal parts of strong alcohol and Squibb's ether and dissolve in it sufficient soluble cotton (gun cotton good quality) to make a thick syrupy solution from which thinner solutions are made.	Place well hardened and dehydrated large specimens in the following solutions: 1.Strong alcohol and Squibb's ether-equal parts-24h 2.Thin celloidin .... 24 hours. 3.Thicker Celloidin .... 24 .. 4.still thicker celloidin .... 24 .. Small specimens may be infiltrated in a few hours.
	2.Paraffin.	Mix together hard and soft paraffin in such proportion that the mixture melts at about 50°C the temperature of the surrounding air being 17°C. Best for small specimens. A good paraffin stove is essential.	Place well hardened and dehydrated small specimens in the following: 1.Alcohol 95%-100% .... 6-24 hours. 2.Chloroform or oil of cedar .. 6-24 .. 3. Paraffin bath .... 1-6 .. 4.Paraffin bath .... 1-2 .. 5.Paraffin bath .... 1 .. In the place of No. 3. a bath of Chloroform saturated with paraffin may be used with advantage.

Preparation of Normal Tissues.

Processes.	Methods.	Preparation	Process
6. Embedding	1. Blocks.	It is necessary to fasten celloidin specimens to a block in order to cut thin sections with a knife. Vulcanized Fiber may be obtained in the market and is good; but satisfactory blocks may be made from bass-wood 1X¾X¾ inches. They will not stain alcohol to any extent and provide a solid support. One end of the block should be sawed ⅛ inch from one side and ¼ inch deep for the string which attaches the tag upon which is written the name or number of the specimen.	Place a little of the thickest celloidin on the end of a block. In this arrange the specimen and pour over it a liberal supply of the same celloidin. Set it to one side for two or three minutas, then place block in 80% alcohol where it may remain until it is needed. Sections may be made after 6 hours. Or specimens may be embedded in a solid block by wrapping a strip of stiff paper around the end of the block allowing it to project above the specimen and filling the well thus formed with Celloidin and placing in 80% alcohol.
	2. Boxes. Molds.	Take stiff paper 4½X2½ inches and fold it along the lines of the diagram below and a box will be made which will hold melted paraffin.  Or two L shaped pieces of heavy metal ½ inch thick and 1 inch long in the clear may be placed upon a flat surface wet with glycerine thus. ⌐ and a mold may be made which will hold melted paraffin. These boxes and molds may be used for either paraffin or celloidin.	Fill the boxes or molds ⅓ full of melted paraffin. Allow the surface to stiffen by cooling. Place specimen in proper position near one end, fill the boxes or molds full of melted paraffin and set them aside to cool. When solid tear off the paper and trim the paraffin blocks. They are then ready for cutting. Or small specimens may be embedded in a block of paraffin by melting the central part of one end with a hot wire and introducing the specimen into the melted place and allowing it to cool.
	3. Freezing..	Tanks of CO_2 under liquid pressure may be obtained from CO_2 manufacturers or makers of microscopic supplies: or a small ether spray apparatus may be obtained from any microscope maker. CO_2 is the quickest and best.	Place specimens on plate of freezing apparatus and cover them well with sugar solution: A. Gum Acacia . 60 grams; water .... 90cc B. Loaf Sugar 225 grms; water 250 cc. Add 4 parts of A to 5 of B. Carbolic Acid 0.3 grms.
7. Cutting.	1. Razor	Any good razor ground flat on the lower side as it is held in position to cut toward you. In the study of fresh specimens a good double knife is essential.	Place specimens between pieces of hardened liver or pith and cut sections by hand. Cut sections with the double knife wet with water from any fresh organ.
	2. Microtome	A mechanical device for cutting sections of uniform thinness. If a number of sections are to be cut an automatic microtome is the best. They are all so constucted that sections of any desired thinness may be obtained consistent with the character of the tissues.	The block of wood or paraffin upon which or within which the specimen is embedded is placed in the jaw of the microtome and sections of uniform thinness are cut. The knife should be kept wet with 80% alcohol when cutting celloidin sections and dry when cutting paraffin sections

Preparation of Normal Tissues

Processes.	Formulae and Methods.		
8. Preserving.	Celloidin blocks.	May be kept in 80% alcohol indefinitely.	
	Paraffin blocks.	May be kept in a cool place indefinitely.	
	Celloidin sections.	May be kept in alcohol, Glycerine, water, equal parts, indefinitely	
9. Fixing paraffin Sections to Slide.	1. Glycerine Albumin.	Egg Albumin. 10cc Glycerine. 10cc Camphor-Small piece.	A Small drop is rubbed evenly on a clean slide. A section is placed upon it and held over a flame until the paraffin is melted. The albumin is coagulated and the section is fixed to the slide.
	2. Distilled water.	Place a large drop of water on a clean slide, float the specimen on the surface of the drop, hold over the flame until the paraffin is smooth, drain off the water and dry in an oven at 30°-35°C. for 30 minutes or until needed.	
	3. Japanese Method.	Rub a little glycerine albumin on a clean slide and place in an oven at 70°C. until dry. Then use the water method above described or with the addition of one drop of glycerine albumin to 30cc of water.	
10. Fixing Celloidin Sections to slide.	Collect Celloidin sections on strips of paper by pressing them upon the blade of the knife. Paint a clean glass slide with very thin Celloidin, place the paper strips with section side down on the thin dried layer of celloidin and a little pressure will make the sections adhere to the celloidin. Remove the paper strips and Keep the sections moist with 70% alcohol.		

	Stains	Formulae.		Preparation
11. Staining.	1. Hansen's Hematoxylin.	Sol. A.	Hematoxylin .... 1 gram. Alcohol 10cc	After 24 hours standing mix in a porcelain dish Sol. A and Sol. B Add 3 cc of Sol. C and with Constant stirring boil one minute. Filter. This stain may be used immediately. It gives good results and is easily and quickly made. Keeps well.
		Sol. B.	Potash Alum .... 20 gms. Hot water 200cc	
		Sol. C.	Potassium Permanganate .. 1 gram Distilled Water 16cc	
	2. Delafield's Hematoxylin.		Hematoxylin .... 4 grams Absolute Alcohol .... 20 cc Sat. aq. sol. ammonia alum .. 400cc Alcohol 95% .... 100cc Glycerine 100cc	Dissolve the hematoxylin in the absolute alcohol, add the alum solution, let stand in an open vessel 4 days, filter, add the 95% alcohol and glycerine. After several days filter again. This stain may be used pure or diluted and gives good results. Keeps well.

Preparation of Normal Tissues

Stains.	Formulae.	Preparation.
3. Böhmer's Hematoxylin.	Hematoxylin.................. 1 gram Absolute alcohol............. 10 cc Potash alum.................. 10 grams. Distill'd water.............. 200 cc	Dissolve the hematoxylin in the alcohol, the alum in the water and mix. Expose to light and air 14 days when it is ready to filter and use. Stain sections ½ hour. If overstained wash in HCL - 10 drops to 100 cc of 70% alcohol.
4. Friedländer's Hematoxylin.	Hematoxylin.................. 2 grams Potash alum.................. 2 grams Absolute alcohol............. 100 cc Distilled water.............. 100 cc Glycerine.................... 100 cc	Dissolve the hematoxylin in the absolute alcohol and the alum in the water. Mix the two solutions and add the glycerine. Filter and expose to light and air for several weeks or until the odor of alcohol is gone. Filter a second time. If nuclei are to be brought out use the acidulated alcohol above.
5. Ehrlich's Hematoxylin.	Hematoxylin.................. 2 grams Absolute alcohol............. 60 cc Glycerine .... 60 cc Distilled water .... 60 cc Glacial acetic acid.......... 3 cc	Dissolve the hematoxylin in the absolute alcohol, add the alum-glycerine mixture and acetic acid, expose to air and light for a long time or until it is a deep, red color.
6. Pal-Weigert Hematoxylin.	1. Hematoxylin............... 1 gram Absolute alcohol............. 10 cc Sat. aq. sol. Lithium Carbonate.. 7 cc Distilled Water.............. 90 cc Mix shortly before using. 2. Lithium Carbonate......... 4 grams. Distilled water.............. 100 cc Prepare the day before using 3. Potassium Permanganate...... 0.5 gr'm. Distilled water.............. 200 cc May be kept in stock 4. Oxalic acid............... 1 gram Potassium sulphite........... 1 gram Distilled water.............. 200 cc Prepare the day before using	Harden the tissues in Müller's Fluid. Soak the sections several hours in 1% aq. sol. chromic acid. Stain for 24 hours in Sol. 1. Wash in water containing 2 cc to 100 cc of Sol. 2 Differentiate in Sol. 3. 1 to 5 minutes Decolorize in Sol 4. Wash in water. Dehydrate. Mount.
7. Hemalum.	Hematein..................... 0.5 gram Absolute alcohol............. 25 cc Potash alum.................. 25 grams Distilled water.............. 500 cc	Dissolve the hematein in the absolute alcohol with the aid of heat. Dissolve the alum in the water. Mix the two solutions. Filter. Add a crystal of thymol.

Preparation of Normal Tissues

Stains	Formulae	Directions
8. Heidenhain's Hematoxylin.	Hematoxylin .... 1 gram Absolute alcohol .... 10cc Distilled water 90cc	Mix and allow the solution to remain in an open vessel 4 weeks and before using dilute with an equal volume of water. Fix the sections 24 hours in Zenker. Wash 24 hours in running water. Dehydrate in ascending alcohols. Fix sections on the slide and immerse in a 2.5% iron-alum solution 4 to 8 hours. Rinse in water. Stain in the hematoxylin solution 12 to 24 hours. Rinse in water and place again in the iron alum solution until black clouds cease to arise. Dehydrate.
9. Mallory's Hematoxylin.	1. 10% aq. sol. Ferric Chloride .... 2. 1% aq. sol. Hematoxylin .... 3. ¼% aq. sol. Ferric Chloride	Fix sections on the slide. Stain in (1) three to five minutes. Blot. Pour over them a few drops of (2) freshly made. Allow the stain to remain 3-5 minutes. Wash. Differentiate in (3) Wash. Dehydrate. Clear in ol. origanum.
10. Kultschitzky's Hematoxylin	Hematoxylin .... 1 gram. Absolute alcohol .... 10cc 2% aq. sol. acetic acid 100cc	Dissolve the hematoxylin in the alcohol. Add the acetic acid solution. Valuable in staining nervous tissue.
11. Eosin....	Eosin (sol. alcohol) .... 1 gram Alcohol 95% 100cc	Stains cytoplasm. Apply 2 to 3 minutes.
12. Silver...	Silver Nitrate .... 1 gram Distilled Water 100cc	Wash fresh tissues in distilled water. Immerse them in the silver solution 5 minutes. Rinse in distilled water and expose to bright sunlight in water, alcohol or glycerine. Mount in glycerine or dry them on the slide and mount in balsam. The silver is deposited in the cement.
13. Osmic Acid	Osmic Acid .... 1 gram Distilled water 100cc	Place the sciatic nerve of a cat in the osmic acid solution for a day or two. Wash and keep in 70% alcohol until needed. Stains fat black.

Preparation of Normal Tissues

Stains	Formulae	Directions.
14 Golgi's Stain.	Sol. A. Müllers Fluid .... 3 vol's Osmic Acid 1% Sol. aq. .... 1 vol Sol. B. Silver Nitrate .... 1 gram Distilled Water .... 150 cc Sol. C. Silver Nitrate .... 1 gram Distilled Water .... 150 cc Formic Acid .... 1-2 drops	Place small pieces of nervous tissue in Sol. A one to eight days, then transfer to Sol. B for ½ hour in the dark, then to Sol. C for 24 hours or more, then to 96% alcohol ½ hour. The sections are mounted in Xylol Balsam which is allowed to dry on the slide; no cover glass is used.
15. Cox-Golgi Stain.	Sol. A. 5% aq. Sol. Potass. Bichrom. .... 40 cc Sol. B. 5% aq. Sol. Mercuric Bichlor. ... 40 cc Sol. C. 5% aq. Sol. Potass. Chrom. ... 32 cc Distilled Water .... 88 cc These solutions may be kept in stock and mixed in the above proportions when used.	Place small cubes of brain and cord in 10 to 20 volumes of the foregoing solution for 6 to 10 weeks changing them as follows: 24 hours, 3 days, 8 days, 15 days, 21 days, 30 days. Transfer to 95% alcohol 1 hour, alcohol and ether equal parts ½ hour, celloidin 1 hour, mount on a block, clear in Xylol 3, Carbolic acid 1 part, in which they may be kept for weeks. Cut, mount on slide, cover with cover glass.
16. Ehrlich's Triple Stain. Blood	1. Orange G Sat. aq. Sol. .... 130 cc 2. Acid Fuchsin Sat. aq. Sol. .... 100 cc 3. Methyl Green Sat. aq. Sol. .... 125 cc 4. Distilled Water .... 300 cc 5. Alcohol .... 200 cc 6. Glycerine .... 100 cc	Mix 1, 2, 4, 5 and add slowly 3, 6. Fix the films by heat or in equal parts of alcohol and ether. Stain 3 to 10 minutes. Wash in water Dry in air. Mount. Red blood cells are brick red, all nuclei light green, eosinophiles fuchsin red, neutrophiles violet red.
17. Wright's Blood Stain	1. Sodium Bicarbonate 0.5% aq. Sol. 2. Methylene Blue 1.% aq. Sol. 3. Eosin (yellow. Sol. in water) 0.1% aq. Sol. 4. Methyl Alcohol	Mix (1), (2) in a flask and steam 1 hour in a sterilizer. When cold pour into large dish. To 100 cc add 500 cc of (3). Stir until the solution is purple, scum yellow, metallic, precipitate black. Collect precipitate and dry it. To 100 cc of (4) add 0.3 gram of the precipitate. Filter. To 80 cc of the filtrate add 20 cc of methyl alcohol. To stain: Dry film in air. Apply stain 1 minute adding, drop by drop, water until stain is semitransparent - 2 minutes. Wash. Dry. Mount. Red cells, orange, nuclei blue, eosinophiles red, neutrophiles lilac, basophiles blue black.

Preparation of Normal Tissues.

Stains	Formulae	Directions
18. Eosin and Methyl Blue	Few drops of a 5% aq. sol. eosin in 1:10000 Caustic Soda Solution. Few drops of Sat. aq. sol. Methyl Blue in 1:10000 Caustic Soda Solution.	Place the film, fixed in Mercuric Bichloride solution, in the eosin mixture 5 minutes and in the methyl Blue mixture 2 minutes wash. Dry. Mount.
19. Eosin and Methyl Blue.	Sat. alcoholic Sol. Ehrlich's blood eosin. Sat. aq. Sol. Ehrlich's Methyl Blue one week old	Place film in eosin solution a few seconds, wash, and place in methyl Blue solution 1 minute. wash and repeat as necessary. Dry. Mount
20. Eosin and Methyl Blue.	Sat. aq. Sol. Methyl Blue............ 40 cc ½% sol. eosin in 75% alcohol....... 20 cc Distilled water................. 40 cc Mix	Place film in the mixture 5 to 8 minutes. Wash. Dry. Mount.
21. Eosin and Hematoxylin	Hansen's Hematoxylin 1% Sol. eosin in 70% alcohol	Place film in the hematoxylin 5 to 10 minutes. Wash. Place in the eosin Sol. 2 minutes. Wash. Dry. Mount.
21. Jenner's Blood Stain	Jenner's Blood Stain. Best procured from Manufacturers.	Place film in the stain 3 minutes. Wash. Dry. Mount.

Blood Smears.

Preparation of Blood Smear	1. Cut strips of cigarette paper a little narrower than a slide, draw one end of the paper through a drop of blood and along the surface of a clean slide Fix. 2. Place a drop of blood upon a clean slide near one end and draw the end edge of another slide through the drop along the surface. Fix. 3. Place a drop of blood upon a cover glass and another cover glass upon it. Slide the two apart without pressure. Fix. In all cases the object is to secure a thin even layer of blood
Fixing Methods.	1. Place film in Sat. aq. Sol. Mercuric Bichloride 1 minute. wash. Dry in air. 2. Place film in an oven at 125°C for 20 minutes. 3. Pass cover glass film through Bunsen flame until too hot for the hand. 110°C 1 minute. 4. Heat slide film 110°-120°C. 1 minute. 5. Place film in equal parts of alcohol and ether 30 minutes. Dry in air 6. Place film in Formaline 1 cc to strong alcohol 200 cc. for 5 minutes Dry in air 7. Place film in 95% alcohol 30 minutes. Dry in air. 8. Place film in a 2.% aq. Sol. Chromic Acid ½ minute. wash Dry in air. 9. Expose film to vapor of osmic acid 2 minutes. 10. Expose film to vapor of Formaline 5 minutes. 11. Place film in Zenker's Fluid 15 minutes. Wash thoroughly. Dry in air. Any one of the above methods may be used.

Preparation of Normal Tissues.

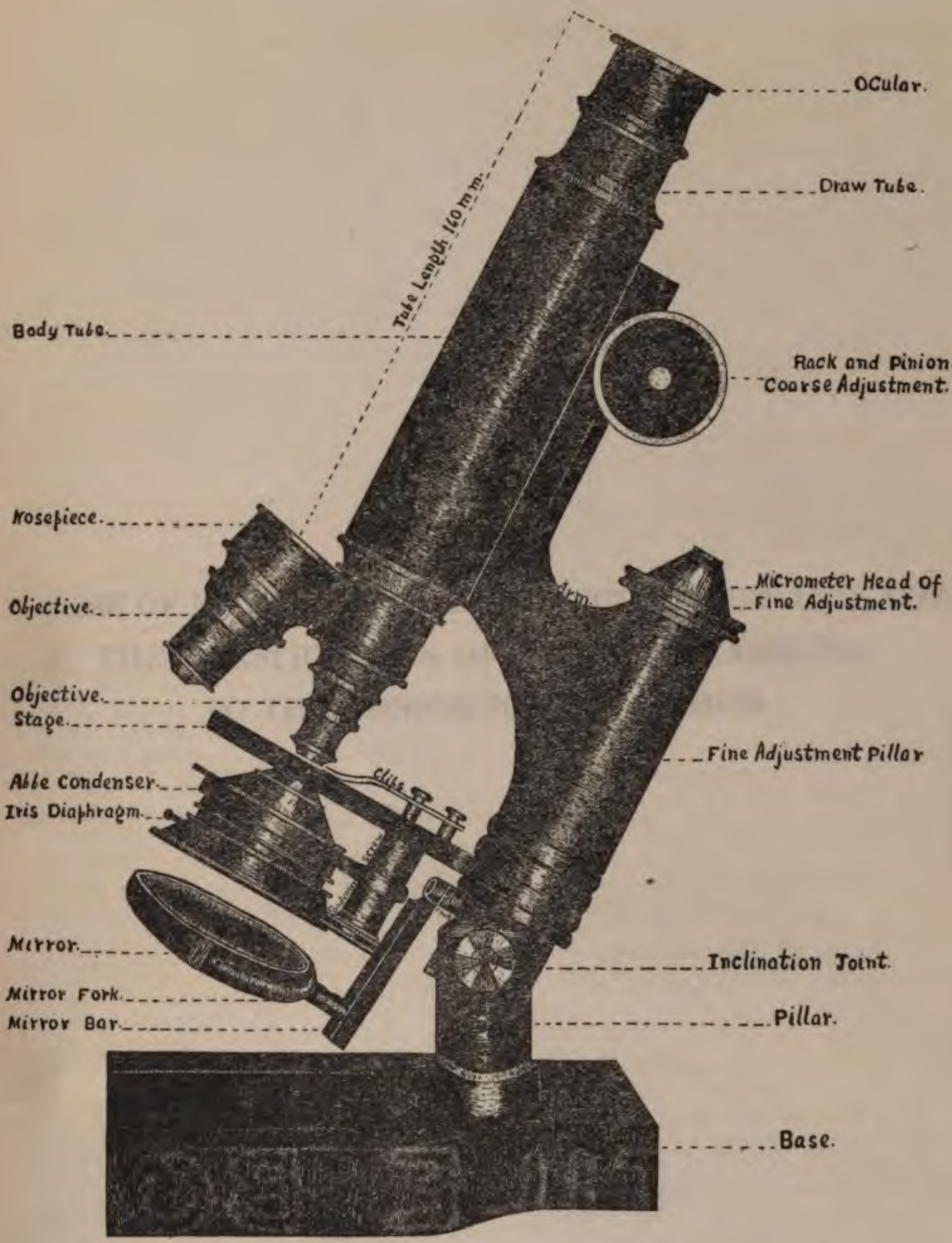
Clearing ag'nts.	Formulae	Actions.
1. Turpentine Carbolic Acid.	Turpentine .... 675 cc Carbolic acid Crystals melted .... 450 cc Filter while hot	Clears well. Does not dissolve Celloidin. Cheap - as the best grade of Carbolic acid is not necessary. Acts quickly. Dissolves eosin slightly. If the mixture Crystallizes add a little alcohol.
2. Xylol ...	Xylol	Acts quickly. Clears well. Soon evaporates. Shrinks and wrinkles sections if left in too long. Does not dissolve aniline dyes.
3. Carbol Xylol ..	Carbolic acid Crystals melted .... 200 cc Xylol .... 600 cc	Acts quickly. Clears well. Soon evaporates. Does not dissolve Celloidin. Dissolves aniline dyes - eosin excepted.
4. Creasote.	The best German beech wood Creasote	Clears well. Does not dissolve Celloidin.
5. oil of Bergamot.	Light green oil of Bergamot	Clears well. Does not dissolve Celloidin. Dissolves eosin - not other aniline dyes.
6. oleum origani cretici.	oleum origani cretici, light brown Color	Clears well. Does not dissolve Celloidin. Dissolves aniline dyes slowly.
7. oil of cloves.	oil of cloves	Clears well. Dissolves Celloidin and aniline dyes rapidly.
8. Sandalwood.	oil of Sandalwood	Clears well. Acts slowly. Dissolves aniline dyes - but not Celloidin.
9. Dunham's mixture.	oil of cloves .... 100 cc oil of Thyme .... 400 cc Filter if Cloudy	Clears well and quickly. Dissolves aniline dyes; but not Celloid. Makes Sections brittle.
10. oil of Cedar.	oil of Cedar	Clears well. Dissolves aniline dyes but not Celloidin.
	In all cases it is necessary that Sections are well dehydrated. If not they will present a milky appearance when placed in the Clearing agent and should then be thrown away or placed in absolute alcohol and the clearing process tried again	
The Double Stain.	1. water 2. Hematoxylin .... 2-4 min. 3. Rinse in water 4. Eosin .... 2 min. 5. Alcohol .... 2 min. 6. Clearing agent .... 1 min. 7. Transfer to slide 8. Blot 9. Balsam (Xylol)	10. Cover glass

The Microscope.

	Parts*	Description.
1. Mechanical	1. Stage.	A Square or circular platform covered with hard rubber, provided with apertures of various diameters for the passage of light and attached to fine adjustment pillar. It is provided with clips which hold slides in place during their examination.
	2. Inclination Joint	A joint at the upper end of pillar by the use of which the body of the microscope may be inclined to any angle between the perpendicular and horizontal.
	3. Coarse Adjustment.	A rack and pinion device by means of which the body tube, with nosepiece and objectives, is raised and lowered by means of the large screw at the back of the arm and near its upper end.
	4. Fine Adjustment.	A micrometer screw at the top of the fine adjustment pillar by the use of which the body tube, nosepiece and objectives are raised and lowered to very slight degrees.
	5. Draw Tube.	The tube within the body tube into the upper end of which fit the oculars and which slides out and into the body tube according to the focal length of tube desired.
	6. Substage.	A mechanical device underneath the stage which carries a condenser and iris diaphragm for illuminating purposes. The whole may be raised or lowered by a screw and swung out or in.
	7. Nosepiece.	A mechanical device with two, three or four society screw openings into which as many objectives may be screwed. It turns on a central pivot so that objectives of different powers may be applied in succession without their removal.
2. Optical.	1. Objective.	A system comprising a front, middle and back lens mounted in a brass cylinder the upper end of which has the society screw for introduction into the nosepiece.
	2. Ocular.	A system of two lenses—eye and field lenses—mounted in the two ends of a short tube which slips into the upper end of the draw tube.
	3. Condenser.	A system of lenses in the substage which is provided with iris diaphragm governing the amount of light received by the specimen.
	4. Mirror.	Flat and concave reflectors of light beneath the substage for illuminating purposes.
	5. Iris Diaphragm.	A mechanical device, resembling the iris of the eye, located in the substage by the action of which the illumination of the specimen may be controlled.

* See cut on opposite page.

Terms applied.	Explanation.
1. Position.	Since the examination of liquids is of frequent occurrence and requires a horizontal stage it is better to become accustomed to the microscope in a perpendicular position. Work with both eyes open.
2. Light.	The best light is obtained from white clouds and from a north window. Best artificial light is from a Welsbach burner or a whitened incandescent bulb. Lamp light may be used with a blue glass between the light and specimen.
3. Focussing.	By this operation the body tube, with its objectives, is raised and lowered by the coarse adjustment until the specimen picture is seen. It is then made distinct by the fine adjustment.
4. Illumination without Condenser.	Symmetrical illumination is essential in the examination of transparent objects and is accomplished by throwing a cone of light from the center of the concave mirror through a diaphragmatic aperture about the size of the front lens of the objective.
5. Illumination with Condenser.	In this case light is concentrated upon the specimen by an Abbé Condenser.
6. Tube Length and Cover glass.	Tube length extends from the eyelens of the ocular to the end of the body tube, usually 160mm. Most objectives are corrected to .15 to .18mm cover glass.
7. Magnifying power.	This property depends upon the objectives and oculars and is in inverse ratio to the focal distance.
8. Flatness of Field.	The presentation of all parts of the microscopic picture in the same horizontal plane.
9. Working Distance.	The distance in the clear between the cover glass and objective.
10. Numerical Aperture.	Ratio between the refractive index of the medium between the object and front lens and half of the angular aperture.
11. Angular Aperture.	Angular breadth of the pencil of light which the objective transmits from the object.
12. Resolving Power.	The ability of the objective to show detail.
13. Penetration.	Power of the objective to show sharply objects in different planes without change of focus.
14. Definition.	Chromatic Aberration. Coloring produced by the passage of white light from one medium to another of different refractive index at an angle greater or less than 90°. Spherical Aberration. Convergence of rays of light arising from one point of a spherical surface to different foci.
15. Oculars.	These parts magnify the image sufficiently to bring out all the details. The higher the ocular the greater the loss of illumination.


Ocular.
Draw Tube.
Tube Length 160 mm.
Body Tube.
Rack and Pinion.
Coarse Adjustment.
Nosepiece.
Arm.
Micrometer Head Of
Fine Adjustment.
Objective.
Objective.
Stage.
Fine Adjustment Pillar
Clips
Abbe Condenser.
Iris Diaphragm.
Screw
Condenser
Mirror.
Inclination Joint.
Mirror Fork.
Mirror Bar.
Pillar.
Base.

PART II

A CASE OF MODELS WITH ARCHITECTIVE OUTLINES FOR THE CONSTRUCTION OF ORGANS ACCORDING TO THE CONSTRUCTIVE METHOD

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